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# THIAMIN AND GROWTH OF CERTAIN FUNGI

BY

R. K. SAKSENA AND D. DAYAL

(DEPARTMENT OF BOTANY, UNIVERSITY OF ALLAHABAD)

(Received 18 March 1944)

## ABSTRACT

*Achlya dubia* Coker, *Aphanomyces camptostylus* Dresch, and *Thraustotheca clavata* (de Bary) Humm are capable of unlimited growth on a medium free from thiamin or its moieties. These organisms are capable of synthesizing their own thiamin from the elementary ingredients of the nutrient medium and some of the thiamin manufactured by the organisms is also given off by the mycelium into the solution. The addition of thiamin to the nutrient medium has no marked effect on the growth of these organisms.

## INTRODUCTION

Fungi other than obligate parasites may be classified into two groups: those that are capable of synthesizing their own growth promoting substances from the simple ingredients of the synthetic media, and those that must secure these from extraneous sources. A large amount of data on the relation of vitamins to the growth of fungi has accumulated rapidly. The reader is referred to the recent publication of Robbins and Kavanagh (1942) for the literature on this aspect.

Leonian and Lilly (1937) have reported that the addition of yeast extract to a medium consisting of  $\text{KH}_2\text{PO}_4$ ,  $\text{MgCl}_2$ ,  $\text{MgSO}_4$ ,  $\text{NH}_4\text{NO}_3$ , and dextrose permitted the growth of *Plectospira gemmifera* and *Saprolegnia diclina*. Later they (Leonian and Lilly, 1938) tested the effect of thiamin on *Achlya conspicua*, *Aphanomyces camptostylus*, *Isoachlya monilifera* and *Saprolegnia parasitica* etc., without obtaining any positive results. They (Leonian and Lilly, 1938) have also reported that *Thraustotheca clavata* fails to make an appreciable growth on a synthetic medium and that it does not respond significantly to thiamin or its moieties but must have biotin.

The present investigation was taken up with a view to find out whether the three organisms, viz. *Achlya dubia*, *Aphanomyces camptostylus* and *Thraustotheca clavata* require thiamin for their growth from an extraneous source.

# MATERIAL AND METHODS

The cultures of *Thraustotheca clavata* (de Bary) Humph. and *Aphanomyces camptostylus* Dresch. were obtained from Central Bureau voor Schimmelcultures, Baarn, Holland. *Achlya dubia* Coker was isolated from a local sample of water.

The methods used were, in general, those communicated in earlier papers (Saksena, 1940; Saksena and Bhargava, 1941; and Saksena, 1941) As far as possible guaranteed reagents were used. Thiamin was obtained from Merck and Co. All the experiments were run in triplicate.

## EXPERIMENTAL

The following nutrient media were prepared:—

Medium A contained 0.5 gm. each of  $K_2HPO_4$  and  $MgCl_2 \cdot 6H_2O$ ; 2.0 gm. of  $NH_4NO_3$ ; 0.05 gm. of cystin; 5.0 gm. of pure dextrose and 1000 c. c. of distilled water.

Medium B contained all the ingredients of Medium A but in place of 2.0 gm. of  $NH_4NO_3$  there was 1.0 gm. of purified asparagin and 1.0 gm. of  $NH_4NO_3$ .

Medium C contained all the ingredients of Medium B but distilled water was only 250 c.c.

The following experiments were performed:

*Series I.* Flasks containing media A, B and C were inoculated with *Phytophthora erythroseptica* and *Phycomyces Blakesleeanus* (+ strain) but there was no appreciable growth in any case.

*Series II.* 25 c.c. of medium A was poured in 150 ml. Erlenmeyer Pyrex flasks which were autoclaved and inoculated with *Achlya dubia*, *Aphanomyces camptostylus* and *Thraustotheca clavata*. All the three species grew well on this medium and were indefinitely transferable on it.

*Series III.* Flasks containing 60 c.c. of the medium A were inoculated with *Achlya dubia*, *Aphanomyces camptostylus* and *Thraustotheca clavata*. The cultures were kept in diffused light at room temperature (23°—25°C) for 14 days.

- (a) In the case of each fungus the mycelium of the three flasks was removed and washed well in distilled water. It was ground and added to 200 c.c. of medium B which was then heated in an autoclave for 5 minutes at 5 pounds' pressure, filtered sterile and poured in five sterilised flasks. These were then incubated for three days at 30°C. The uncontaminated ones were inoculat-

ed with the test fungi viz. *Phytophthora erythroseptica* and *Phycomyces Blakesleeanus*

- (b) 25 c.c. of the medium C was added in the case of each fungus to 125 c.c. of the staled medium from which the mycelium was removed as described under Series IIIa. The pH of the medium was adjusted to 7 by N/10 KOH solution and it was then filtered sterile and poured in five sterilised flasks. The flasks were then incubated for three days at 30°C. The uncontaminated ones were inoculated with the test fungi. It was found that the test fungi gave appreciable growth in each case

*Series IV.* Medium B was supplemented with thiamin in different concentrations (5 units and 25 units per 25 c.c. of the medium) and experiments were performed on both liquid and solid media. The inoculum was cut off from the margin of a young colony growing on the solidified medium B. Medium B alone served as a control. Diametric growth of the colonies was measured after 24, 48 and 72 hours, and dry weights were taken after 15 days of inoculation. The results are summarised in Tables I and II.

TABLE I

Diametric spread (in cms.) of the fungus colonies on solidified medium B, with or without thiamin

Fungi.	At the end of (hrs.)	Medium B (control)	Medium B supplemented with thiamin.	
			5 units.	25 units.
<i>Achlya dubi</i>	24	0.9	0.9	0.8
	48	1.8	1.8	1.8
	72	2.7	2.8	2.7
<i>Aphanomyces camptostylus</i>	24	1.6	1.6	1.5
	48	3.4	3.3	3.2
	72	5.0	4.9	4.8
<i>Thraustotheca clavata</i>	24	1.0	1.0	1.0
	48	1.7	1.6	1.6
	72	2.2	2.2	2.2

TABLE II

Dry weights (in mg.) of the fungus colonies grown for 15 days in flasks containing 25 c.c. of medium B, with and without thiamin

Fungi	Medium B (control)	Medium B supplemented with thiamin.	
		5 units	25 units.
<i>Achlya dubia</i>	36.0	33.0	34.6
<i>Aphanomyces camptostylus</i>	30.0	28.0	26.3
<i>Thraustotheca clavata</i>	42.7	39.0	39.0

## DISCUSSION AND CONCLUSIONS

It is now well established that the growth of *Phytophthora erythroseptica* and *Phycomyces Blakesleeanus* is controlled by thiamin or its components, and since it has been demonstrated above that they show no appreciable growth on media A, B and C (Series I), it is clear that media A, B and C were free from the significant amount of thiamin, pyrimidine and thiazole.

The results of experiments under Series II show that *Achlya dubia*, *Aphanomyces camptostylus* and *Thraustotheca clavata* were able to grow indefinitely on medium A which was free from thiamin or its intermediates, it is therefore clear that these fungi do not require thiamin from an extraneous source for their growth.

Since the test fungi grew well on medium B when the extracts of mycelium of the fungi under investigation were added to it (Series IIIa), it can safely be assumed that the required thiamin and probably its intermediates were present in the extracts and that it was contained inside the mycelium of the fungi under investigation, which must have synthesized it from the ingredients of medium A. Similarly from the results of experiments of Series IIIb it is evident that some of the synthesized thiamin was also given off by the mycelium of the fungi studied into medium A. Thus these fungi behave like *Saprolegnia delica* Coker (Saksena and Bhargava, 1941) and some species of *Pythium* (Saksena, 1941) which synthesize their thiamin from the ingredients of the nutrient medium.

Results of experiments carried under Series IV and tabulated in Tables I and II indicate that the addition of thiamin has no marked effect on the growth of the fungi under investigation.

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# EFFECT OF PRE-SOWING TREATMENT ON THE DROUGHT RESISTANCE IN RICE

BY

P. PARIJA, O.B.E., M.A. (Cantab.), I.E.S. & K. P. PILLAY, M.Sc.,

BOTANICAL LABORATORY, RAVENSHAW COLLEGE, CUTTACK

(Communicated by Prof. B. Sahni F.R.S.)

(Received 24 November, 1944)

## INTRODUCTION

In a previous publication (1) one of the authors (Parija) has reported the results of investigations carried out in connection with inducing drought resistance by presowing treatment on one variety of winter paddy. It was recorded therein that the water requirement of the treated plants was significantly less than that of the controls. Further studies have been undertaken on a summer variety of paddy, *Dalu*, during the summers of 1942-43 and 1943-44, the basis of the pre-treatment being exactly on the same lines as published before. Experiments were also conducted to study the capacities of treated and untreated plants to endure severe wilting, as this forms, according to the Russian worker Maximov (2), the basis of drought resistance. The results of these investigations having been promising are embodied in this brief paper.

So far, to our knowledge, no record has been made in India of similar experiments on Rice. Henckel and Kolotova (3) have reported the effect of pre-sowing treatment on drought resistance in wheat conducted in Russia. They found that, when plants were subjected to severe wilting the amount of water lost by the treated plants was less than that of the untreated during the period of wilting. In his investigations on the drought resistance of Indian Wheats, Chinoy (4) observed that plants raised from pre-treated seeds reached anthesis earlier than the control. Experiments conducted by Kar on jute (5) at the Bose Research Institute showed that under identical conditions of drought, the percentage of wilting is less in the treated plants than that in the untreated and, on addition, of water, the recovery was greater in the treated sets.

(a) *Water requirement studies*

## METHOD

The procedure of the experiment was similar to that reported earlier except for certain minor details. The initial soil moisture in the tin pots had to be maintained at 35% by adding the calculated amount of water (1400 c c ), because at 25% moisture level, most of the plants were found to wilt in the hot summer months owing to excessive transpiration. Instead of covering the open face of the pots by cellophane paper, oil cloth was used this time. The treated and control plants were each divided into three groups of 8 plants each. These three groups represented the three intervals of watering of 8, 10 and 12 days. At the end of each interval, the respective sets of plants were weighed carefully and the loss in weight, which was due solely to transpiration, was made good by adding the required quantities of water. This process was continued up to harvest and the total transpiration was thus computed. From this and the total dry matter produced (excluding roots) the water requirement for each plant was worked out. The yield of grain was also recorded. The duration of the experiment was about 170 days.

## RESULTS AND DISCUSSION

The results of the experiments conducted in 1942-43 summer are presented in Table I. Statistical analysis could not be done to evaluate the significance of the results obtained owing to the inadequacy of the number of plants. There was only one interval of watering (8 days) in this case.

*Table I*

Mean values per plant summer paddy 1942-43. (8 days interval of watering).

Treatments	Transpiration (gms.)	Dry weight of tops (gms.)	Yield of grains (gms.)	Water requirement
Treated ...	11,020	10.18	0.28	1,084
Control ...	12,540	9.77	0.12	1,288

The mean values given above indicate that the transpiration and water requirement of treated plants are lower than those of the untreated by 12 and 16 per cent respectively. There is no appreciable difference in the dry weight



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of tops The yield of treated plants appears to be greater but this is not confirmed by later experiments.

The data collected in 1943-44 have been statistically analysed at the Statistical Laboratory, Calcutta and the results are summarised in the accompanying tables .

*Table II*

Means of transpiration per plant (summer paddy 1943-44.)

Intervals of watering	Treated	Control	Difference
8 days	11245	11975	730
10 days ...	9321	9887	566
12 days	8640	8898	258

CD. = 810.4

*Table IIA*

Analysis of variance — transpiration.

Variations due to	D. F	S S	Variance	F	5% F
Treatments ...	1	3224033	3224033	4.88*	4.08
Interval ...	2	68207504	34103752		
Interaction	2	457930	228965	0.35	
Error ..	42	27721525	660036		

*Table III*

Means of water requirement per plant

Intervals of watering	Treated	Control	Difference
8 days ...	986	1077	91
10 days ...	988	1045	57
12 days ...	1036	1107	71

C. D. = 80 at 5% level.

„ = 107 at 1% level.

*Table IIIA*

Analysis of variance—Water requirement.

Variations due to	D. F.	S. S.	Variance	F.	5% F.	1% F.
Treatments ...	1	68875	68875	10.08	4.08	7.31
Interval ...	2	25770	12885			
Interaction ..	2	2375	1187	0.19		
Error ...	2	265934	1331			

*Table IV*

Means of yield of grains per plant.

Interval of watering	Treated	Control	Difference
8 days ...	1.21/	1.20	0.01
10 days ...	1.15	0.64	0.51
12 days ...	0.60	0.63	0.03

*Table VA*

Analysis of variance—total dry matter

Variations due to	D. F.	S. S.	Variance	F.	5% F.
Treatments ...	1	0.225	0.235	0.250	4.08
Interval ...	2	74.083	37.041		
Interaction ...	2	0.160	0.080	0.085	
Error ...	42	39.411	0.938		

\*indicates significant at 5 % level.

\*\*indicates significant at 1 % level.

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From the statistical analysis, it becomes clear that the transpiration and water requirement of treated plants are significantly less than those of the controls. There is, however, no difference in the yield of grains or the total dry matter produced.

An examination of the results for the two years indicate that, in general, the behaviour of the plants in both the seasons is similar. Transpiration and water requirement of treated plants were less than those of the corresponding controls in both the years. The total dry matter produced in treated and control plants does not show any appreciable variation for both the years. Thus, for the production of the same amount of dry matter, the treated plants require less water than the untreated ones. That is to say, pre-treatment increases the efficiency of the plant, and thus enables it to withstand drought.

(b) *Wilting studies in the seedling stage before transplantation (1942-43).*

The treated and the untreated plants behave in a differential manner under restricted water supply even in the seedling stages. This is indicated by the following observations in connection with wilting and recovery recorded before transplantation.

<i>Dates.</i>	<i>Time.</i>	Number of plants wilted.	
		<i>Treated.</i>	<i>Control.</i>
4-2-1943	2.30 P. M.	43	57
do	3 P. M.	93	97
do	4 P. M.	500 c.c. water added.	
do	4.30 P. M.	6	12
6-2-1943	2.30 P. M.	39	48
7-2-1943	10.30 A. M.	28	57
9-2-1943	11.15 A. M.	33	50
do	12 noon	42	58
do	2.45 P. M.	83	92
do	2.50 P. M.	500 c. c. water added.	
do	3 P. M.	38	42

<i>Dates.</i>	<i>Times.</i>	<i>Number of plants wilted.</i>	
		<i>Treated.</i>	<i>Control.</i>
9-2-1943	3.5 P. M.	none	17
do	3.15 P. M.	none	17
10-2-1943	2.30 P. M.	9	24

*(c) Wilting studies after transplantation (1943-44)*

## METHOD

Treated and control plants of uniform size were transplanted to 8 glazed stone-ware pots, each pot being provided with one treated and one control plant. These were at first allowed to grow under normal water supply. After 60 days from sowing, 4 pots each containing a treated and a control plant were left unwatered until they had wilted completely. The remaining 4 pots were also similarly treated when the plants were 88 days old, the object being to study the capacity of plants to withstand severe wilting at two different ages. Finally, a record was made of the number of plants which survived and the number which died from both the sets.

## RESULTS

The observations recorded in connection with wilting are recorded below:—

Age 60 days—Pots 3, 4, 7 and 8, each containing one treated and one control plant were left unwatered from 6-4-44.

<i>Date.</i>	<i>Time.</i>	<i>Pot. Number</i>	<i>Wilting.</i>	
			<i>Treated.</i>	<i>Control.</i>
11.4.44	5 P. M.	3	Not wilted	Slightly wilted
		8	Slightly wilted	Slightly wilted
12.4.44	10.45 A. M.	3	Not wilted	Completely wilted
		8	Slightly wilted	Completely wilted

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Date.	Time.	Pot. Number.	Wilting.	
			Treated.	Control.
		4	No difference between treated and control.	
		7	Both in turgid condition.	
do.	12. 30 P. M.	3	Not wilted	Completely wilted
do.	5 P. M.	3	Slightly wilted	Completely wilted
		4	Slightly wilted	Slightly wilted
13.4.44	8 A. M.	3	Commencing to wilt	Completely wilted
		8	Slightly wilted	Completely wilted
		4	Slightly wilted	Slightly wilted
do.	5 P. M	7	Treated and control plants in all pots have completely wilted.	
15.4.44	4 P. M.		500 c.c. water added to all pots.	
16.4.44	8 A. M.	3	Completely revived	Slightly revived
		8	Completely revived	Not revived
		4	Revived	Revived
		7	Completely revived	Slightly revived
			Plants again left unwatered	
24.4.44	9.30 A. M.		All plants wilted	Completely
	do.		1000 c c. water added to all	
do.	4 P. M.	3	Completely revived	Slightly revived
		4	Completely revived	Slightly revived
		7	Slightly wilted	Slightly wilted
		8	Completely revived	Not revived
do.	5 P. M.		500 c.c. water added to all	
25.4.44	8.45 A. M.	3	All treated and control plants revived. But treated, in general, are healthier and have revived to a greater extent than the untreated.	
		4		
		7		
		8		

These plants are allowed to grow under normal conditions.

Date.	Time.	Pot. Number.	Wilting.	
			Treated.	Control.
17.5.44		3	Completely revived and same state as that starting normal growth by putting forth fresh leaves and tillers on 25th April 1944	
		4	Revived	.. Died.
		7	Died	Died
		8	Revived	... Died.
12.6.44		3	Growing normally	.. Growing normally.
		4	Growing normally	. Died.
		7	Died	. Died.
		8	Growing normally	.. Died.

Thus out of 4 treated and 4 control plants, to start with, 3 treated and one control plant survived.

Age 88 days—Pots 9, 10, 11 and 14 left unwatered from 4th May 1944.

10.5.44	...	...	All plants completely wilted.	
do.	...	..	1,000 c. c. water added	
18.5.44	Morning	9	Revived	. Not revived.
		10	Wilted	... Wilted.
		11	Slightly revived	... Not revived.
		14	Wilted	... Wilted.
			1,000 c. c. water added	
17.5.44	Morning	9	Revived fully	... Completely wilted.
		10	Slightly revived	... Wilted.
		11	Completely revived	... Wilted.
		14	Slowly reviving	... Slowly reviving.

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These plants allowed to grow under normal conditions.

Date.	Time.	Pot. Number.	Wilting.	
			Treat.	Control.
12.5.44		9	Growing normally	.. Dead.
		10	Growing normally	... Dead.
		11	Growing normally	.. Dead.
		14	Dead	... Growing normally.

Out of 4 treated and 5 control plants ultimately one survived in the control set and 3 in the treated.

#### SUMMARY AND CONCLUSION

The observations recorded above indicate that the treated plants of summer paddy, locally known as *Dalua*, withstand drought conditions better than the untreated within the limits of our experiments. The survival of plants when they are subjected to severe wilting is greater and recovery, on addition of water, is sooner in treated than in the untreated ones. Even in the seedling stage wilting is much less in the treated set than in the control. It is also found that the transpiration and the water requirement of the plants subjected to the pre-treatment are significantly less, showing thereby, that they require less water than the untreated for the production of the same amount of dry matter. Thus pre-sowing treatment induces resistance against drought in summer paddy. Probably repeated soaking and drying of the seeds several times might induce still greater resistance to drought.

#### ACKNOWLEDGMENT

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# NOTES ON THE ANATOMY OF THE STRIDULATING APPARATUS OF *GRYLLUS SIGILLATUS*. (WALKER.)

BY

RAM NATH MISRA, M.Sc.

DEPARTMENT OF ZOOLOGY, AGRA COLLEGE, AGRA

(Communicated by Prof. D. R. Bhattacharya)

(With six text-figures)

(Received 2nd May, 1944)

## ABSTRACT

The following important features have been revealed from a study of the Stridulating Apparatus of *Gryllus sigillatus*:—

- (1) The tegmen of either side bears a file.
- (2) Scraper is altogether unrepresented.
- (3) The dorsal region of the mesothorax bears on either side stiff bristles against which the file strikes to produce the sound.
- (4) In the position of rest the right tegmen overlaps the left one

## INTRODUCTION

Members of certain groups of insects like Orthoptera, Coleoptera, Hymenoptera and Lepidoptera are capable of producing sound of different types and intensities. The mechanism for the production of sound has been thoroughly studied in a number of insects but it seems that *Gryllus sigillatus*, the common Indian Kitchen cricket has escaped close observation. The author's findings do not conform to the types already described in the Family Gryllidæ. Different views have been put forward regarding the importance of sound in the life of insects. In this connection Leo J. Bair's experiments and observations are very instructive; he concludes that insects are stimulated to produce sound by external influences and one of the many factors which initiate chirping of the male is the approach of a female or to indicate its own presence. *Gryllus sigillatus* was selected for study as it is easily available and it is capable of producing a very shrill note which denotes a high degree of development of the sound-producing organ. It is a nocturnal animal, and rarely comes out during the day time when it frequents dark and shady corners in almost every house. The insect is especially abundant in kitchens where it lives upon pieces of food left over. They are easily caught during night time when they come out in search of food.



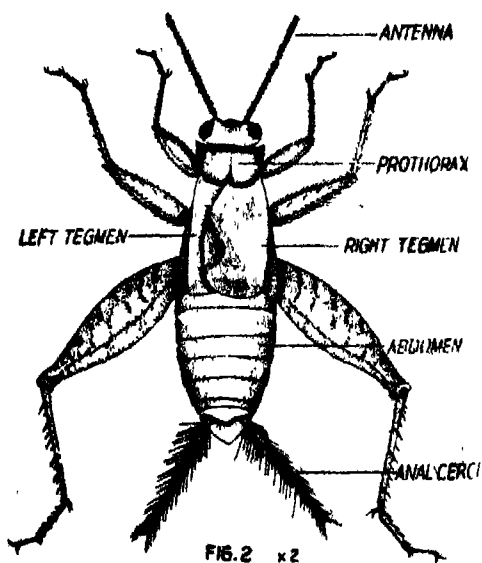
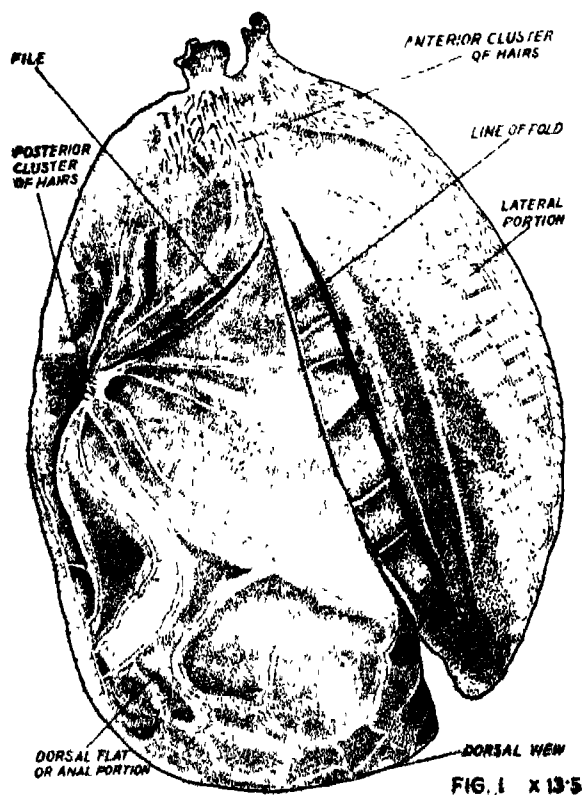
# METHOD AND TECHNIQUE

For purpose of study the insects in living condition were kept in glass jars in a darkened room. These jars were covered with close fitting wire-gauze lids and at the bottom a layer of finely sifted earth about two or three inches in thickness was laid. The insects were fed on raw meat or dough on which they seem to thrive well.

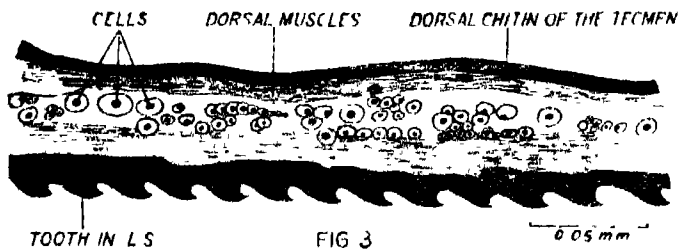
The tegmina from the different stages of development of the insect were removed and flattened by keeping them between two slides which were tied with rubber bands on either end. After dehydration, clearing was done in clove oil. Tegmina from nymphal stages when plucked invariably brought with them tuft of muscles which had to be cleared in a weak solution of caustic-potash.

## STRIDULATING APPARATUS

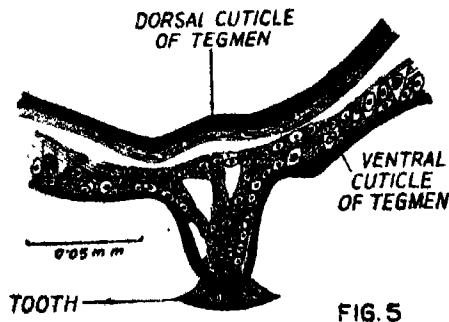
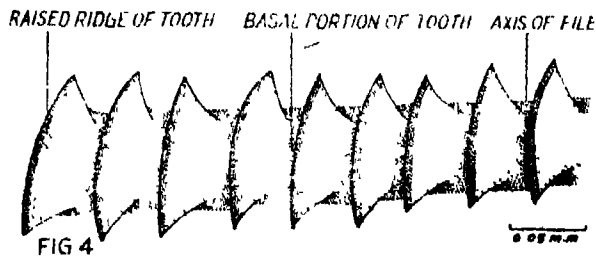
The female *Gryllus sigillatus* is wing-less, whereas the male which is comparatively smaller than the female possesses a pair of wings correspond-



ing to the tegmina of other insects. These tegmina are not so fully developed as in other allied insects like *Gryllodes melanocephalus* (the field-cricket), but remain small so that the greater part of the hinder region of abdomen remains uncovered. The tegmina are not adapted to flight but they mainly serve the purpose of stridulation. They are attached to the antero-lateral borders of the meso-thorax and in the fully developed male they extend behind upto the third abdominal segment. Each tegmen is composed of a broad portion which lies on top of the meso-thorax and the three anterior segments



of abdomen, and a narrower lateral portion which is applied to the sides of the abdomen (Fig. 1). When the tegmina are lying at rest the flat dorsal portion of the right overlaps the corresponding portion of the left, leaving uncovered a small area of the left tegmen (Fig. 2).



The stridulating apparatus in this insect consists of a file and large stiff bristles. The former is borne by the tegmina and the latter are found on the dorso-lateral surface of the mesothoracic tergum.

The file can be seen from the dorsal side of a tegmen as a dark chain-like line which starts from the anterior end of the lateral fold (which separates the dorsal flat part of the tegmen from the lateral part) and runs obliquely backward in a curved fashion to near the free anal margin of the tegmen. At this end all the veins of the dorsal flat part of the tegmen converge and the tegmen bears a large number of well developed bristles

#### STRUCTURE OF THE FILE

It consists of a central cuticular axis developed on the ventral side of a vein. It bears a series of teeth which vary in number from 114 to 122 in the fully developed file. The teeth are largest in the centre and gradually diminish in size towards either end of the axis. Each tooth is roughly triangular in shape and is attached to the axis by its apex and its broad slightly curved base hangs freely ventrally. The teeth arise at an inclined angle from the axis (Figs. 3 and 4).

The bristles, as mentioned before, are situated on the dorsolateral side of the mesothoracic tergum on either side.

#### MECHANISM OF STRIDULATION

During stridulation the tegmina are raised at an angle of about 45 degrees to the back of the animal (Fig. 6) and they are rapidly moved sideways to produce the characteristic rattling noise. The files of either tegmina which seem to rub against one another do not do so, but they rub against the dorso-lateral surfaces of the mesothoracic terga which bear on either side

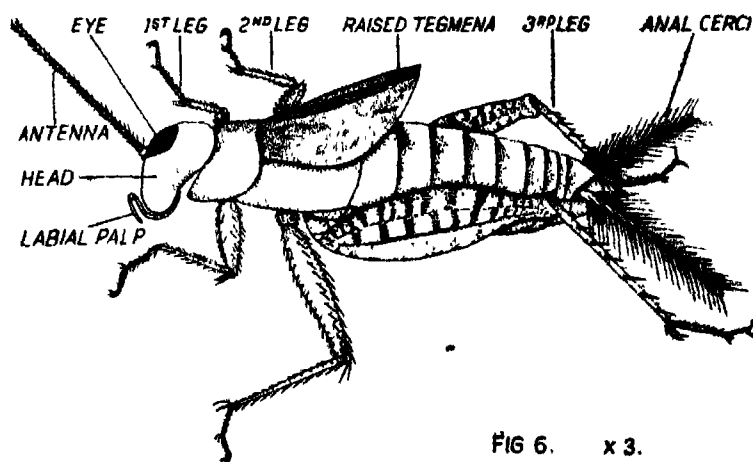


FIG 6. x 3.

localised patches of numerous large stiff bristles. Sound is produced by the rubbing of the teeth of the file against these bristles. There is thus no specialised area of thickened chitin either on the tegmen or on the mesothorax which may act as scraper against which the file may rub as has been described in the family Tettigonidæ and Gryllidæ. In the male *Microcentrum laurifolium* of which the stridulating apparatus has been thoroughly studied, the left tegmen bears a file-like organ while the opposite one bears a scraper and the sound is produced by the rubbing of the file against the scraper. The *Gryllodes sigillatus* is different from others in producing sound by the friction of the file against spines on the mesothoracic tergum. In Tettigonidæ and Gryllidæ no part of the thorax has been shown to serve as stridulating apparatus. In the Family Cerambycidæ of the Order Coleoptera, however, the hind margin of the prothorax rubs against the base of the scutellum to produce sound.

#### ACKNOWLEDGMENTS

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# ON THE ORIGIN OF DOUBLE MONSTERS\*

BY

GEORGE POLITZER

Patiala

(With eight figures)

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## ABSTRACT

The modern theories on the origin of double monsters are based on the observations made on higher fish, birds and mammals. This is due to the fact that medical authors are mostly interested in the origin of the human monsters, besides malformations of this type are rather rare in animals of the other classes of vertebrates. Nevertheless the cases published by me in 1926 furnish sufficient material on duplicities of amphibia to point to the remarkable difference between them and those of the other classes. As these observations have been confirmed on further material collected by me and by the publications of some Japanese authors in the *Folia Anatomica Japonica* they are now sufficient in number for the discussion of the problem which is the subject of this paper.

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### *I.—The difference between the double monsters of amphibia and those of fish, birds and mammals.*

In the first part of my above quoted paper (Politzer 1926 a) I proved beyond doubt—and it has been confirmed since then—that there exists no posterior duplicity in amphibia and that all relative specimens published up

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\*From the Princess Surrendra Kumari Memorial Central X-Ray Institute, Patiala.

to then as well as all described by me were no cases of real duplicities. Further observations by Japanese authors confirmed the correctness of my conclusion. They were cases of exstrophy of the entoderm with subsequent independent development of the paired tail tubercles which could not unite to an unpaired tail bud due to the presence of the inverted entoderm. This could be proved by the presence of a big kind of yolk plug whose outer surface had already developed into the epithelium of the intestines with all the typical cellular differentiations characterising this area. On both borders of the plug and even further on towards the head, where the intestines were inside the body and nearly normal, notochord and spinal cord showed normal differentiation to about half-size organs. The two tails were highly asymmetric due to the underdevelopment of their inner (opposite) sides. Only their tips showed rudimentary signs of postgeneration of the muscles. These observations proved beyond doubt that *the so-called posterior duplicities of the amphibia were no duplicities at all but the result of an incomplete invagination of the entoderm with subsequent self differentiation of the ectopic organs and rudimentary regulation and postgeneration of the non-united portions.* It can be presumed, that this abnormal gastrulation is caused by an abnormal size of the entomesodermic area on the surface of the blastula.

The systematics of the malformations in man and birds contain a special group whose main representative is the *craniopagus parasiticus* (Fig. 1). A second head is present connected with the head of the autosite by the vertices of the skulls. The irregularity of this malformation is manifest from the fact that both faces are looking to different sides and the different specimens observed so far showed remarkable diversity of the angles of the symmetric planes of both heads: The same irregularity is found in the rare cases, in which both partners of a *craniopagus* are endowed with trunks and limbs. This irregularity in the axes and planes of the partners characterises also the other representatives of this group of double monsters. In a paper I published together with *H. Sternberg* in 1929 we tried to distinguish typical and atypical malformations. The first group containing amidst many others the polydactyly, the harelips, palate clefts a.s.o. are characterised by a great similarity of cases of the same ilk and by the heredity of the malformation. The atypical malformations are those in which the different specimens show a diversity even of essential features. While the first group is due to the retardation, incompleteness or disturbance of a well defined part-action of the embryological processes, the second group derives from accidental interference of unusual factors during the development. Observations on germdiscs of birds containing two embryonal primordia show clearly that the

craniopagus derives from a secondary coalescence of the heads of primarily disparate embryos. To make this deduction clearer I attach Fig. 2 which is a simplified sketch of a malformation observed by myself. It is now most interesting and important for the conclusions drawn in later chapters of this paper that no specimen of duplicities in amphibia has been observed so far, which belongs to the above group of double monsters.

All in all it can be said that all the double monsters of amphibia observed so far are typical anterior duplicities. The only difference between the different specimens observed so far lies in the extent of the duplication. Where asymmetries could be observed (as f.i. in one case in my second paper on duplicity of urodeles 1926 b) they are of secondary nature and do not concern the early processes of development during which the occurrence of a duplicity is decided. Let us see the importance of this observation! In agreement with the general theory of the origin of double monsters *Newman* distinguishes three different ways by which twins and double monsters may originate.

No. 1. A young blastoderm may divide into partly united partly separate blastodermata. If both of them produce embryos they will be partly united partly separated.

No. 2. A single blastoderm loses its axiate organisation so that two separate gastrulation centres appear. If these two gastrulation centres are near to each other they are bound to fuse earlier or later into a single one, so that again a double monster will originate.

No. 3. An originally single axis will separate incompletely into two branches.

There is much discussion about the reality of these three possibilities, each one being sustained by observations and experiments. But it has not been tried so far to examine them on the applicability to amphibia.

Ad No. 1. Let us suppose that in the entodermic area of the late blastula of an amphibian egg two invagination centres should appear instead of one. The result will be that two separate invagination streams will be formed and two separate archentera will arise. But as soon as the material between the two invagination centres will have been used up the two separate streams will unite into a single one. That means that the archenteron of the gastrula as a whole will become Y-shaped, the length of the paired cranial extremities dependant on the former distance between the two invagination centres.

There is ample evidence in the embryologic literature, the descriptive and experimental as well, that the archenteron acts as an organizer (*Spemann* and *Mangold* 1924) inducing the formation of the brain out of the overlying ectoderm. It means that the occurrence of a double invagination centre will lead to a typical anterior duplicity, the extent of the duplication dependant on the initial distance of the invagination centres,

Ad No. 2 Let us suppose that originally one single point on the blastula is destined for the start of the gastrulation, but for reasons unknown this primarily single invagination stream separates later on into two disparate ones. The result will be a Y-shaped archenteron, the length of the paired components dependant on the degree of independance of the two branches. Again under the influence of the archenteron as organizer an anterior duplicity of various degree of duplication will result.

Ad No. 3. The discussion of this third point is a bit more complicated because the incomplete isolation of two blastomeres or groups of blastomeres will not remain permanently manifest due to the syntactic influences, the surfaces of the cells are exercising on each other. But luckily the experiments of *Spemann* (1901, 1902, 1903) give a clear answer to this question. It *Spemann* tied a thin hairsling around the furrow demarcating the two first blastomeres from each other and removed it afterwards the germ appeared entirely normal uptil the inception of the gastrulation. But during the invagination the stream of cells divided into two divergent components, with the result that duplicities of various degrees arose. But all of them were anterior duplicities and if the string was tied too tightly the result was no anterior duplicity but fullfledged twins. Thus it can be presumed that incomplete isolation of blastomeres may result in no manifest changes uptil the gastrulation and later on in the formation of anterior duplicities of various degrees.

Concluding it can be said that *whatever theory we like to apply to amphibians they always will explain the occurrence of anterior duplicities only what tallies well with the above mentioned observation that no other double monsters but anterior duplicities have been found so far.* The interference between twins leading to malformations of the type of figures 1 and 2 cannot take place, as the twin embryos of amphibia are isolated from each other and not growing on the same germ disc as in birds.

## *II. The difference between natural and experimental duplicities of amphibia and its importance.*

The development of the experimental embryology in the beginning of this century led to the discovery of different methods to obtain double mon-



sters artificially. No wonder that some less cautious authors tried to explain the natural occurrence of duplicities as a repetition of the experimental factors in nature. Sometimes this task was a difficult one. As *Spemann* found that incomplete constriction of an early germ along the furrow of the first cleavage-division by a hairsling leads to the occurrence of an anterior duplicity, *Grochmalicki* and *Kaufmann* believed that a similar action could be exercised by a fold of the wall of the uterus, in which the ova of the salamandrinae develop. Apart from the fact that such an action is hardly imaginable, the probability would speak for an irregular constriction of the ovum along any meridian of the globe. *Spemann* has now shown that already a slight deviation of the sling from the furrow leads to cyclopic defects of one partner of the duplicity. It should be thus expected that duplicities found in nature show this anomaly in nearly all cases, while only one single badly described case of *Klausner* exists in the whole literature, which may possess such a defect as postulated above. The famous theory of *Stockard* based on his experiments on fundulus has found many supporters. Temporary arrests in the development may lead to discoordination of the part-processes of the development. As there is a critical period for each step in the development this critical moment may lapse due to a temporary slowing down or arrest of the development. It is quite probable and even proved by experiments that the lapse when once having happened can no more be regulated in a normal form. But this shall be discussed later. Also the findings of *Werber* have attracted great interest as some of the chemical substances by which he was able to obtain malformations do appear in the pathological metabolism as *f.i.* butyric acid. But all these interesting juxtapositions and analogies miss the essential point that there are marked differences between the malformations found in nature and those obtained by experimental interference.

No. 1. Fig. 3 shows one of the many anterior duplicities obtained by *Spemann* by constriction of triton ova by hairslings along the first furrow during cleavage. Compare with it Fig. 4 which represents a salamandra larva observed by me. It is clearly visible that both heads of the salamandra larva are approximately of the same size as those of a single normal animal of the same age and size, while the heads in the triton larva of *Spemann* are by far smaller than that. For the same reason the heads of *Spemann's* larva keep some distance one from the other so that there is even some space left between both filled by the gills of both heads. In the larva described by me the heads do not find room for their adjustment and as visible in a front view of the faces of both heads one has partly slipped above the other (Fig. 5).

Fig. 6 shows a simplified drawing of the famous dicephalus of *Broman*, in which the size of heads and limbs show the same relations of size as described in my larva. Concluding it can be said that *the doubled parts in a duplicity found in nature show equal size to those of a normal animal of same age and length, while in malformations obtained artificially the doubled parts are about half size*. Exact measurements to confirm this statement have been made by *Tan Jur*, *Terni* and myself but they are not necessary to be related here in detail because the reproduced figures are self evident.

No. 2. Another difference between both kinds of malformations can be seen in the figures 3, 4 and 6. The larva of *Spemann* shows a very slender trunk even where the two heads are branching off. The larva described by me and the dicephalus of *Broman* possess broad trunks which diminish slowly in diameter towards the caudal end of the body. The explanation for this difference is obtainable from the study of the condition of the inner organs. In experimental malformations the outer and inner duplication end nearly in the same level while in the duplicities found in nature organs are doubled even in an area which apart from its abnormal breadth appears in its outer aspect to be single. Concluding it can be said that *in nature malformations the duplication of inner organs is by far more extensive than that of the outer appearance while in artificial ones both nearly coincide*.

The comparison between malformations obtained by experiments and those found in nature shows marked differences which admonish us to be careful in our attempts to prove that similar factors prevail in nature and in our experiment.

### III. *Regulation and regeneration of size of primordia of organs of amphibia.*

It has already been mentioned in the first chapter of this paper that whenever we apply the constriction by hairsling to the ovum of a triton which leads later on to its developing into a double monster, the irregularities in the developmental processes will not start before the gastrulation. In spite of all the differences in the development of the amphibia with their typical total invagination and the discoidal development\* of the teleostei, birds and mammals similar conditions are prevailing also in other classes. The physiological polyembryony of the armadillo and similar animals (*vide Newman*) becomes not manifest before the appearance of the primitive knot and stripe. But even if there are some differences as to be expected from the rare cases of

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\*This does not mean discoidal cleavage which does not occur in higher mammals.

apparition of disparate cleavage in one or the other higher vertebrate it does not affect our conclusions when we confine them purposely to amphibia.

For them it can be maintained that the first anomaly to be observed will be the atypical gastrulation which instead of forming a straight archenteron will lead to Y-shaped formations. It has already been mentioned that this foregut once it has been formed acts as an organizer and converts the overlying ectoderm into medullary plate. The fact that there exists a kind of predetermination for the formation of medullary plate already in a previous stage as proved by *Lehmann*, *Bautzmann* and others does not affect our conclusions in any way as this predetermination is not fixed but alterable under the influence of the underlying organizer. But if such a Y-shaped invagination takes place in an otherwise normal ovum then the material consumed for the two disparate foreguts will be equal to that normally used for one foregut only. As the size of the medullary organs is dependant on the size of the organizer as proved by the experiments of *Mangold* and others, the two heads of the anterior duplicity must remain below normal size as in the malformations obtained by *Spemann*. This conclusion which is of the greatest importance for the following chapters stipulates that *the primordia of the organs when once determined can no more be changed in size*. This statement shall be exemplified by some observations from the experimental literature. The experiments of *Wachs* have shown that the regenerative forces of the eye of the larva of the newt is nearly illimited. If only the pigment epithelium (tapetum) of the eye was left after an operation it suffices to regenerate the retina as well as the lens. *Spemann* (1912) on the other hand inverted a part of the ectoderm of the dorsal surface of the very young germ of tritons so that the eye primordia have been divided into two halves located now at different places of the embryo. None of these four reduced eye primordia developed into an eye of normal size, but all formed undersized replicas of normal organs. Also in microphthalmic larvae of salamandra found in nature no regeneration or regulation to normal size takes place. The same observations could be made in other organs as the heart (*Stoehr*), the limbs (*Harrison*) and the tail (*Bergel, Politzer* 1929). Thus it can be said that *the anterior duplicities of the urodeles are formed by Y-shaped invagination and that the conditions found in the natural duplicities can only be explained if we presume that the area on the surface of the blastula destined to form the roof of the foregut was increased in size already before the gastrulation set in* as otherwise the duplicities resulting from Y-shaped invagination would look like those obtained by *Spemann* and not like those found by me.

#### IV. *Experiments on ova of amphibia leading to disproportionate distribution of primordia on the blastula.*

Based on the famous experiments of *Vogt* and his school a chart could be mapped out showing the position of all essential organs as primordia on the surface of the blastula. I have reproduced this famous chart in another paper published in these proceedings (*Politzer 1944*). But the relative size of these organogenetic areas can be changed by experimental interference. *Herbst*, later *v. Ubisch* and *Lehmann* achieved a relative increase of the vegetal area of the ovum by submitting the eggs of the sea-urchin to the influence of lithium salt. The opposite result, the relative increase of the animal area can be obtained by rhodanides (*Lindahl, Runnstroem*). This falls in line with older experiments of *Driesch, Herbst, Fischel* and others who obtained various malformations by help of changing the chemical environments in which the ovum was developing. But chemical agents are not the only means by which a disproportion of the primordia of the organs can be obtained. *Lehmann* and *Runnstroem* showed that the action of these chemical agents bears on the cell respiration and that similar effects can be produced by changing the oxygen-carboxide relation. The change in the cell respiration is not the same in all cells of the germ and, while some will respond with a complete standstill of the cellular life, others will be but retarded in growth, while still others may be left more or less undisturbed. This will lead to a disproportion in size of the primordia of the various organs or germ layers in general and alter the chart of *Vogt* to a remarkable extent. As it has been shown in the previous chapter the disproportions in the size of the primordia when once established cannot be regulated later on to normal conditions, we are drawn to the conclusion that the disproportion of the organs, once established in their primordia by chemical or physical agents, remains unaltered in its essentials also later on and must lead to malformations at least in size. The differentiation of organs are usually based on a proper size of the primordium and it needs careful discussion what alterations we have to expect in primordia increased or decreased in size as compared with their regular condition. This leads to the necessity to discuss the developmental features of the local nanism and gigantism. Concluding it can be said that *chemical and physical agents create disproportion in the size of the primordia of germ layers and organs in the late blastula and early gastrula. This disproportion cannot be regulated in size at a later period of development.*

#### V. *On local nanism and gigantism.*

It is known since long that malformations of size occur in two different forms. Sometimes the abnormal organ is an enlarged or diminished replica

of a normal one and sometimes its abnormal size is only part and parcel of a far reaching abnormality of form and differentiation. It is further known that the localised nanism is more often characterised by normal features of the organ concerned apart from its diminished size, while the local gigantism tends more towards graver anomalies of form and structure. To make the discussion easier, it will prove useful to call an organ or an organism "harmonic" (as suggested by *Driesch*), if the relative size of organs or primordia and their differentiation and distribution is normal, whatever the size of the organism or organ as a whole may be. Adopting this nomenclature, it can be stated that the local gigantism is mostly disharmonic, while the local nanism is usually harmonic. Harmonic gigantism is found, if at all, at the acral parts of the body as fingers, toes, eventually tongue and lower jaw or in young larvae as a whole. Fig. 7 reproduces the famous case of *Streeter*, Fig. 8 a case observed by me. As far as the origin of the gigantism is concerned, we start best from the experiments of *Driesch* in which he succeeded to fuse two sea-urchin eggs to a single one. This giant egg produced mostly giant, but harmonic plutei. But sometimes the plutei showed anomalies which could be interpreted as partial duplicities. The explanation for this attitude of the ova has been given by *Driesch* in connection with the results obtained in another experiment performed by him and *Herbst*. If the blastomeres of the sea-urchin egg are separated one from the other, each one will develop into a pluteus of normal differentiation but of reduced size. *Driesch* argues that each ovum is to be considered as a harmonic-equipotential system, i.e., it is able to produce a harmonic organism, but whose parts possess still the potential capacities of the ovum as a whole which can be realised under abnormal circumstances. If the blastomeres of the ovum are separated each blastomere forms again a harmonic-equipotential system, destined in the normal course of development to form a half embryo only. But its equipotentiality makes it possible that a regroupment takes place which finally leads to the development of a full larva of only reduced size. Similar conditions are prevailing in the giant ova resulting from the fusion of two ova. Here a harmonic-equipotential system is reached by fusion of two systems in a similar way as a harmonic-equipotential system can be obtained by separation of the blastomeres i.e., by halving a system into two. The fact that these giant ova furnish sometimes giant plutei and sometimes more or less complete duplicities shows that the tendency of the giant ovum to form a new harmonic-equipotential system by fusion interferes with the harmonic-equipotential systems which were represented by the two ova which have been fused. The result of this interference is a more manifest duplicity.

The same argumentation fits into the local gigantism, as I have shown in my paper on this subject in 1938. The giant fingers and toes are often simply enlarged replicas of normal ones but sometimes they contain two complete finger skeleta while the outer appearance of the finger (nails, the joint furrows of the skin, the hair pads), is single. The formation of giant fingers can be explained easily by the hypothesis that during the separation of the hand plate into the material for the different fingers the distribution of the material was abnormal so that too much material has been assigned to one of the fingers. This giant primordium formed a harmonic-equipotential system for a finger but some tendencies to partial differentiation as characterising a harmonic equipotential system of a lower order were occasionally realised. Again the same interference between systems of higher and lower order could be 'proved in the case of the local gigantism as it is in existence in the cases of giant ova, where the formation of a giant larva interferes with differentiation to double larvae. How is it now to be explained that these interferences are more often visible in the cases of gigantism than in the cases of nanism? I believe it can be no doubt that this can be only attributed to the fact that the abnormal quantity of material can not be always accommodated into a normal formation but carries in itself the tendency to separate into units of normal size

Concluding it can be said that *while a moderately diminished quantity of a primordium can easily be differentiated into an organ of diminished size, an anomalous increase of material destined for the development of an organ tends to some extent to partial or total duplicity.*

#### VI. *The origin of duplicities*

It has been mentioned previously that no simple analogies can be drawn between the experimental factors leading to the formation of duplicities and those prevailing in nature, already for the simple reason that there are marked differences between the malformations produced artificially and those found in nature. The main difference on which we drew the attention was the size of the doubled parts of the embryos which led us to the postulate that the material destined for the doubled parts of the embryos must have been excessive in size already in the blastula. This means that the duplicities at least of the amphibia are due to an abnormal size of the primordia of the germ layers when still on the surface of the blastula. As the formation of the organs of the head has been proved to be dependant on the dorsal wall of the archenteron acting as an organizer it must be presumed that the area meant for this purpose has been excessive in size already at the end of the blastulation. An unequal distribution of the

primordia of the germ layers can be produced by various agents: Alteration of the cell respiration by *Runnstroem*, changes in the chemical constitution of the water by *Herbst*, *Fischel*, *Lohmann*, *Runnstroem* and others. Even experiments not made for this very purpose as those of *Stockard* or *Werber* can be considered in this connection. Taking this all in mind it can be stated as follows:

No. 1. By chemical or physical anomalies of the conditions surrounding the ovum during the blastulation the area assigned to form the roof of the archenteron occupies a bigger part of the surface of the blastula than usual.

No. 2. If once the primordium of an organ is oversize (or undersize) no late regulation of this disproportion is possible.

No. 3. Oversize primordia although occasionally able to develop an organ of normal form and differentiation, but of excessive dimensions carry in themselves the tendency to develop into duplicities.

No. 4. If once the invagination leads to Y-shaped form of the archenteron however the process may have started the whole anterior end of the larvae will be doubled due to the fact that the development of the head is directly or indirectly dependant on the action of the roof of the foregut as organizer.

No. 5. Duplicities posteriores and irregular double-monsters occur in animals only, where the development of embryos appears in a discshaped area of the ovum (teleostei, birds, mammals).

This hypothesis is valid in first instance for amphibia only, while there may be other factors governing the development of higher fish, birds and mammals. But the advantage of the above hypothesis lies in the fact, that it is in accordance with all the observations made so far in duplicities of amphibia. It tallies also well with the results of various experiments and its purely hypothetical part is exceedingly small. But even these portions which are at present mere presumptions are open to experimental control which I hope to carry out as soon as I am given the necessary opportunities again.

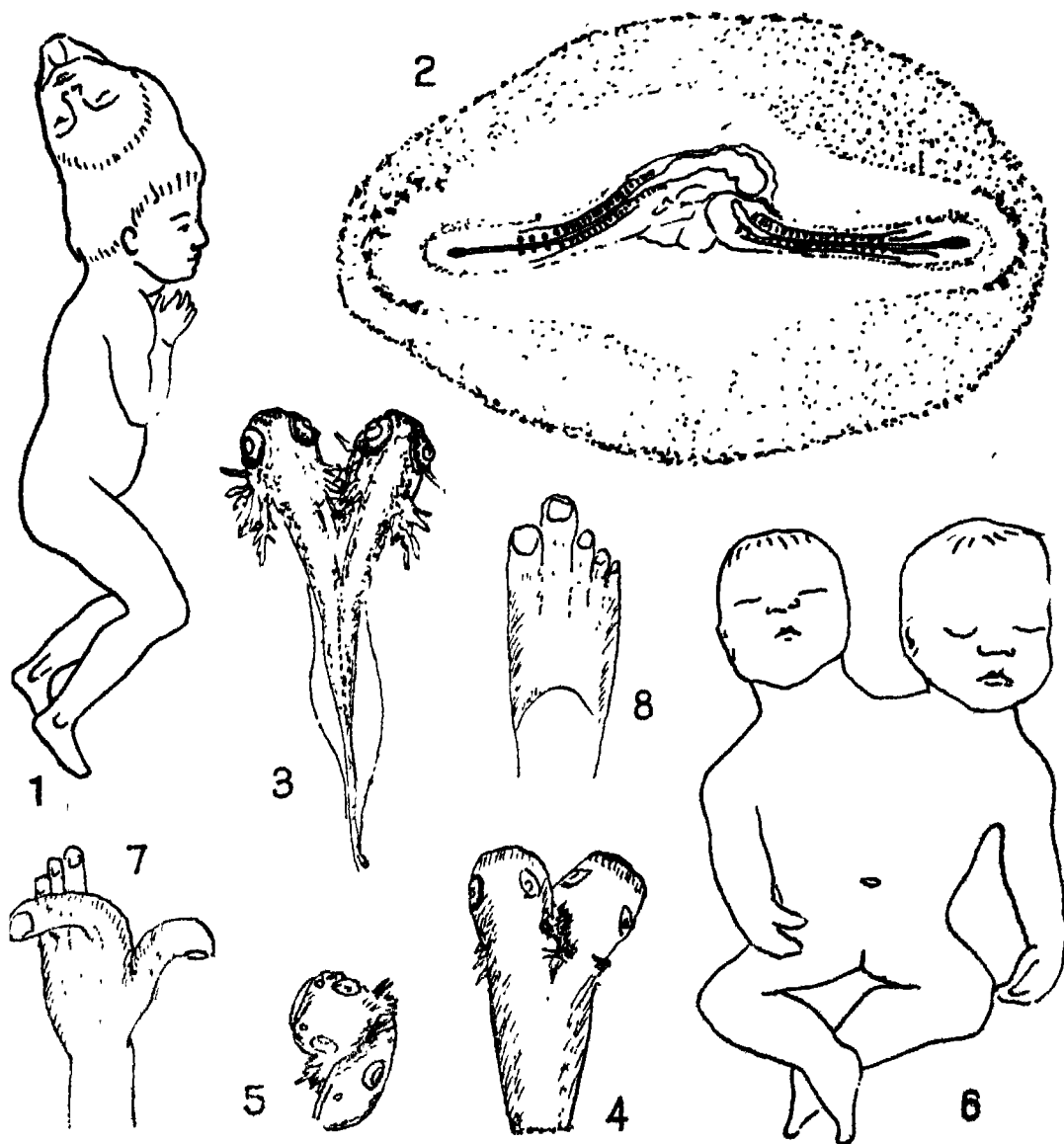
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# PROCEEDINGS

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ALLAHABAD

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A DESCRIPTION OF THE HITHERTO UNKNOWN FEMALE OF  
*AEDES (DICEROMYIA) PERISKELETUS* (GILES) 1902

BY

M QUTUBUDDIN, M.Sc.

MALARIA DEPARTMENT, HYDERABAD, DECCAN

(Communicated by Prof M. Sayeeduddin)

(Received 20 October 1944)

ABSTRACT

Full description of a female mosquito of the species *Aedes (Diceromyia) periskeletus* (Giles) 1902 is given. This species has been hitherto known only from the male sex as first described by Giles in 1902 from Shajehanpur and later by F. W. Edwards in 1914. No specimens, whatever, could be available during a search made by other workers for the last 30 years in the north of India.

The mosquito described here differs from the other 3 Indian species of the sub-genus *Diceromyia* in the presence of femoral pre-apical pale rings and from *A (D) nyangari* Edw. and *A (D) punctipes* Edw. in the coloration of the first hind tarsal segment.

While it resembles in many features, the female differs from the male of *A (D) periskeletus* (Giles) in the broad patches of white scales on the vertex and the absence of white ring on the proboscis.

But as it shows closest affinities to *A (D) periskeletus* it is labelled as such and can not at present be ranked as a new species altogether.

HISTORICAL

This species was first described as *Stegomyia periskelata* by Giles in the year 1902. His description was based on the single type male he caught from Shajehanpur in August 1900. Later F. W. Edwards gave a redescription of the male from Jhansi in 1914, and named it as *Ochlerotatus annulifamur*. P. J. Barraud (1928) in revising the Culicine mosquitoes of India abandoned the two sub-generic names in favour of the sub-genus *Skusea* of the genus *Aedes* and named the species as *Aedes (Skuses) periskeletus* Giles but on further research it was finally sunk by Barraud (1931) under the sub-genus *Diceromyia* which was erected by Theobald in 1911. From the Indian region five species of this sub-genus have been reported till now. No further specimens of the species under description could be collected for the last thirty years by other workers and it was known only from male; female remained unknown till now. The author of the present article during a

survey of the Culicine mosquitoes of Hyderabad (Dn) City came across a single female a description of which is given in the following:—

#### SYSTEMATIC POSITION AND DESCRIPTION OF THE FEMALE

I. *Generic Diagnosis*—The profusely fringed margin of the squama and the ending of the vein 6 well beyond level of the fork of vein 5 rule out three Indian genera *Uranotaenia*, *Harpagomyia*, and *Hodgesia*. The presence of post-spiracular bristles suggests the Indian genera *Mansonia* (*Mansonioides*), *Armigeres*, and *Aedes*. But the slender and straight proboscis decides us to place it as *Aedes* (*Sens-lato*).

II. *Sub Generic Characters*—The simple tarsal claws, scant ornamentation, broad and flat acutellar scales, short first hind tarsal segment, and moderate length of proboscis distinguish it from other sub-genera of *Aedes*. It is distinguishable from the sub-genus *Cancaedes* by the presence of white stripe on head on either side of middle line. The broader and not completely retractile VIII segment of the female; shorter and broader cerci and simple claws separate it from *Aedimorphus*. The presence of a fringe to the squama excludes the sub-genus *Paraedes* erected by F. W. Edwards to receive two Indian species.

III. *Description of the Female*—Black smallish species not conspicuously ornamented. VIII segment broad and not completely retractile; cerci short and broad.

*Head*: Clothed with broad flat scales; black up right scales on naps more than few, two patches or rather bands too broad to be called stripes (stripes in the case of male), of white flat scales on vertex separated by a line of black broad scales in the middle. A line of thinner white scales is continued down to the frons. Proboscis; dark brown with no white ring in middle, (white ring in the case of male).

*Thorax*: Mesonotal scales dark brown; lighter scales on front margin and very few in front of wing roots. Flat white scales on the scutellar lobes are visible.

*Abdomen*: Mainly black scaled with white basal lateral patches more conspicuous on the II, III, and IV tergites.

*Legs*: Black; pre-apical white rings on femora (absent in micropterus (Giles) and reginae Edw. All femora and tibiae narrowly white at tips. Apart from the pre-apical rings, the fore-femora are picked out sub-apically with creamy white, rather, bluish flat scales only on the dorsal side not

forming a complete ring. Thin lines of similar scales are seen from certain angles on the dorsal side of all the femora. All tarsal segments narrowly white at both ends. First hind tarsal segment without pale ring in middle (present in *punctipes* Edw. and *iyengari* Edw.) Wings: brown scaled, a few white ones near the base,

#### DISCUSSION

Thus it is clear that the female typically differs from other Indian species and is closely allied to the male of *A. (D) periskeletus* (Giles), except in the coloration of the palpi and the magnitude of broad white vertical scales. Until, however, a male having characters answering to the above description and differing from the male of *A. (D) periskeletus*, is discovered, it cannot be given the rank of a separate species. It is, therefore, labelled as hitherto unknown female of *A. (D) periskeletus* (Giles).

The single female specimen will be deposited in the Indian Museum as circumstances permit, and the para type, if be available, will be sent to the British Museum.

#### ACKNOWLEDGMENTS

My heartfelt thanks are due to Prof. M. Sayeeduddin, Chairman of the Botany Department, Osmania University for communicating this paper. I have to record my thanks to the Director, Medical and Public Health Department, Hyderabad Deccan for the permission granted to publish this article. I have also to offer my grateful thanks to Dr. M Farooq, Deputy Director, Public Health Department, Hyderabad Dn. for his keen interest and appreciation. I also record my indebtedness to Dr. M.A.B Saberi, Chief Malaria Officer, Hyderabad Deccan for the facilities afforded during the work.

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# ON THE PHYSIOLOGY OF THE PYLORIC CAECA IN A CARNIVOROUS FISH, *OPHICEPHALUS STRIATUS* BL. AND A HERBIVOROUS FISH, *OSPHRONEMUS GORAMY* LACEP.

BY M RAHIMULLAH AND A K DAS

DEPARTMENT OF FISHERIES,

H.E.H THE NIZAM'S GOVERNMENT

HYDERABAD (DECCAN).

(Communicated by Prof. B. Sahni, F.R.S.)

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## ABSTRACT

The contents of the pyloric caeca of *Ophicephalus striatus* Bl., a carnivorous fish, and *Osphronemus goramy* Lacép., a herbivorous fish, were biochemically tested for the detection of digestive enzymes, and the following functions may be assigned to them —

- Possibly act as a storage of reserve or semi-digested food-material.
- Probably absorb the digested food matter like the intestine.
- Are said to be mainly concerned with fat-absorption.
- Partly act as digestive organs—presence of certain enzymes, such as DIASTASE, MALTASE, LIPASE, PEPSIN, and TRYPSIN and also that of the BILE, which affect the digestion of carbohydrates and proteids, and thus help and supplement the digestive processes of other juices poured into the alimentary canal.
- They secrete LIPASE and TRYPSIN in the carnivorous fish (*Ophicephalus striatus* Bl.) and DIASTASE and TRYPSIN in the herbivorous fish (*Osphronemus goramy* Lacép.), because the latter fish requires more diastase to digest the excess of starchy food.

## INTRODUCTION

Some work on the physiology of the alimentary tract in fishes has been done by a few workers amongst whom the most notable ones are Mordecai

(1860), Edinger (1876), Blanchard (1882), Krukenberg (1882), Stirling (1884), Macallum (1886), Bonduoy (1897), Greene (1911), Ben Dawes (1930), Chesley (1934) and Jacobshagen (1937). In India, so far as I am aware, N. B. Desai of Wilson College, Bombay, was working on the "Enzymes of the pyloric caeca of *Scatophagus argus*", but in spite of writing to him several times we could get no reply, and hence his results, if any, are unknown to us.

The present work was undertaken when the senior author was working on the "Morphology, Histology and Physiology of the Pyloric caeca in Indian Fishes" in MS and in the later part of the work the experiments were conducted jointly. Further work is in progress on other fishes.

Besides the results of some workers given on p. 7, I may also refer to the following:—

Chesley (1934) working on the "Concentration of enzymes in certain marine fishes" has arrived at the conclusion that the pyloric caeca are more active in fishes in which the pancreas is diffused and that the caeca seem partially to supplant it in enzyme secretion but where the pancreas is well-developed the caeca have a minor rôle. And furthermore, he says that lipase is least in quantity in fishes having a fatty metabolism (in so far as they store large reserves of fat).

Pernkopf and Lehner state as follows:—

(i) The physiological significance of the "appendices pyloricæ" is uncertain even up to the present day. The opinion of the old anatomists, such as Cuvier, Carus and others, is that they act as a kind of gland.

(ii) Krukenberg, Blanchard and Stirling state that different ferments, partly pepsin, partly trypsin and also diastase, have been proved to be present in the contents of the caeca. According to Blanchard the secretion is alkaline, but according to Claude Bernard it is acidic.

(iii) Jacobshagen denies the presence of enzymes.

(iv) According to other more recent authors, viz., Edinger and Meckel, the caeca perform only the absorption of the digested food, and hence their function is to enhance the absorptive surface of the intestine.

In the abovementioned latest work Jacobshagen, pertaining to certain special problems connected with "appendices pyloricæ", states as follows:—

(a) It has been shown that the "appendices" are bulgings from the forepart of the intestine, and that they possess the character of that part of the gut.

- (b) They are a help to the intestine by increasing its absorptive surface, and that they also act as a food-reservoir.
- (c) The pancreatic- and bile-ducts open very near the origin of the caeca, and their juices have been traced inside them.
- (d) The production of any specific ferment which has been advocated by Claude Bernard, Krukenberg, Blanchard, Stirling and Bonduoy seem to be improbable.

#### MATERIAL AND METHODS

Half a dozen large-sized specimens of *Ophicephalus striatus* Bl. (Fam. Ophicephalidæ) were dissected after pithing; the caeca were slit open, their inside scraped by means of sharp piece of glass the contents were then ground with a little glycerol and sterilized sand in a mortar. It was then centrifuged, and the fluid was drained into two tubes marked (A) and (B) in equal quantities. Tube (A) was put in a water bath and kept in boiling water for 30 minutes to kill all the enzymes and was kept as CONTROL. Tube (B) contained the TEST substance. Material for the herbivorous fish, *Osphronemus goramy* Lacép was prepared similarly for experiments and tests.

For determining the secretory function of the caeca the fishes were dissected as before, their stomach, caeca and the intestine were slit open, washed in running distilled water so as to get rid of all the contents, and then scrapings were taken and material prepared as before.

#### (A) TESTS:

- Four small sample tubes marked 1, 2, 3 and 4 were taken. In Nos. 1 and 2 the test substance was placed in equal parts, and in tubes 3 and 4 the control substance of equal quantity was poured. All the
- (1) Demonstration of the presence of DIASTASE:

tubes were kept overnight in an incubator at 40°C. after adding to each tube 3 c.c. of 2% solution of starch (a drop of toluene being also added to each of these sample tubes to prevent the growth of mould). Next day the contents were tested for diastase by the addition of a few drops of very dilute solution of iodine to all the tubes. In 1 and 2 tube blue colour developed and quickly vanished, but in 3 and 4 the blue colour appeared and persisted, demonstrating that in the test substance DIASTASE was present and had changed the starch more or less completely into ACHROODEXTRIN. This is called the achromic point, i.e., it gives no colour with iodine, whereas in control, the diastase as being one of the available enzymes and having been completely killed by boiling, the starch remained unchanged giving the usual blue colour with iodine.

Fresh substance from (A) and (B) was poured in two sample tubes and starch solution was added to them, and both

- (iv) Demonstration of the presence of MALTASE: were kept at 40°C. in an incubator overnight.

Next day, a drop each from these tubes was put on a filter paper and a drop of Fehling's solution (No. I and II) was put on both the spots. The spots were then impinged with a jet of steam. Control spot showed no change but the test spot assumed brick-red colour. This shows the presence of MALTASE which converts maltose into glucose (the first reaction being that starch is reduced to maltase by the action of diastase, and then maltose is further converted into sugar, such as glucose, by the action of the maltase present).

Fresh substance, as before, was taken into two sample tubes, then 3 c.c.

- (v) Demonstration of the presence of LIPASE: of alkaline emulsion of olive oil was added to both, and the tubes were kept overnight in the incubator at 40°C. Addition of a drop of

methyl red gave no result in the control, but in the test substance a faint orange-red ring appeared at the top, showing the action of the LIPASE present in converting the oil in emulsion partly into fatty acid.

Again, a little of the substance from (A) and (B) was taken into two

- (vi) Fibrin-carminic test for the detection of PEPSIN. sample tubes and kept at 40°C. in an incubator overnight. Then, a few chips of fibrin, stained with ammoniacal-carminic solution, were put

in both the tubes and allowed to remain in the incubator for 15 minutes. Control showed no change, whereas the test substance turned pink owing to the hydrolysis of fibrin by the action of PEPSIN.

Congo-Red-stained fibrin was then put in two sample tubes containing fluid from (A) and (B) and kept at 40°C. inside

- (vii) Detection of TRYPSIN (after Roaf's modification) by Congo-Red test: an incubator. Control showed practically no colour, whereas the test substance was stained red as a result of the action of the proteolytic

enzyme, i.e., TRYPSIN.

Although bile was seen inside the lumen of the pyloric caeca during dissections, yet for the sake of confirmation,

- (viii) Detection of BILE: qualitative biochemical test was also applied.

This is demonstrated by means of the well-known Gmelin's test. On an opal plate a drop of concentrated Nitric acid was put and then a little of the semi-fluid substance from the lumen of the caeca was added to it. At the point of contact, the spot displayed various colours, such as yellow, green,

blue and violet. The reaction is based on the oxidation of the pigment with the formation of coloured derivatives such as, *mesobilirubin*, *mesobiliverdin* and *mesobilicyanin*.

A drop of Phenol Red was placed on an opal plate and a little of the fresh substance taken directly from the lumen of the caecum of a vivisected fish was very quickly added to it. Immediately there was development of a yellowish-red colour, and this was matched with that of the standard chart for hydrogen-ion concentration. The pH in case of *Ophicephalus* was 7.2 and in that of *Goramy* 7.5, and is, therefore, very slightly on the alkaline side.

All the above-mentioned series of biochemical tests were carried out and repeated on the contents of the pyloric caeca of another carnivorous fish of the same family, *viz.*, *Ophicephalus punctatus* Bl., which gave exactly similar results as in the case of *O. striatus*; and, furthermore, these experiments were done on the contents of the pyloric caeca of the herbivorous fish, *Osphronemus Goramy* Lacép, also with the same results.

#### (B) RESULTS:

Below are given the results obtained by other workers and side by side our own obtained after performing the above tests:

Krukenberg	Stirling	Blanchard	Macallum	Rahimullah & Das
Diastase, Pepsin and Trypsin present and absorption of the digested food	Different functions in different fishes: absorptive in some; and in others glandular and secreting Trypsin in some cases.	Diastase and Tryptic Enzymes present which act in acid or alkaline medium.	Lipase, pepsin and Trypsin present, but no Diastase. Suggests some secretory functions also.	Diastase, Maltase, Lipase, Pepsin, Trypsin and Bile present, pH 7.5 ( <i>Ophicephalus</i> ) & 7.2 ( <i>Goramy</i> ), and hence very slightly alkaline

From the above results it is quite evident that the pyloric caeca perform digestive function to some extent, supplementing the stomach, but practically in all other respects they are very similar in action to that of the intestine, in correlation with their resemblance to the latter in histological details.

Having detected the presence of certain enzymes inside the lumen of the pyloric caeca, the next question that at once struck us was—whether the caeca are secretory at all or not; and if so, which of these enzymes are actually secreted by them, and which come from other sources?

Material prepared from the stomach, pyloric caeca and the intestine was subjected to typical biochemical tests for the presence of the different kinds of enzymes, and the results are shown in the table below:—

	Organs	Pepsin	Diastase	Maltase	Lipase	Trypsin
<i>Ophicephalus stratus</i> Bl. (Carnivorous)	Stomach	+	—	—	—	—
	Intestine	—	—	+	—	+
	Caeca	—	—	—	—	+
<i>Goramy</i> Lacép. (Herbivorous)	Stomach	+	—	—	—	—
	Intestine	—	—	+	—	+
	Caeca	—	—	—	—	+

This shows clearly that in *Ophicephalus*, *Lipase* and TRYPSIN are secreted by the caeca, and other enzymes, viz., Pepsin by the stomach; Maltase and Trypsin by the intestine, and some of these are supplemented by the pancreas; while in *Goramy*, DIASTASE and TRYPSIN are secreted by the caeca, and the rest come from the stomach, intestine and the pancreas. Here, it may be noted that in the *herbivorous* fish (*Goramy*) DIASTASE is secreted in Place of LIPASE (secreted by the caeca of *Ophicephalus*, a *carnivorous* fish), because the former is vegetarian, and hence requires more of diastase to digest the excess of starch food.

It is also very interesting to note that the location, formation and distribution of such digestive enzymes as pepsin and trypsin (which are, as a rule, mainly associated with the stomach and pancreas respectively in the higher vertebrates) are very variable in different species of fishes, and not nearly so strictly localised as in the former group of animals. So far from peptic digestion being limited to the stomach, it may take place even in the pharynx, stomach and in the intestine of *Ammocoetes* and in some Elasmobranchs (e.g., *Scyllium*), and in certain Teleosts, such as the Pike, Eel and Carp, the peptic region in these types extending from the stomach up to some distance along the intestine, while trypsin is widely distributed in fishes and has been obtained from the mucous membrane of the stomach, intestine and pyloric caeca as well as the pancreas (*C.N.H. Series, Fishes*, p. 271).

We are, therefore, led to conclude that they serve as accessory reservoirs of semi-digested food and, to some extent, perform the function

of digestion also; absorption of digested food possibly takes place in the same way as in the case of the intestine; secretion of LIPASE and TRYPSIN takes place in the case of the carnivorous fish, viz., *Ophicephalus*, and that of DIASTASE and TRYPSIN in the herbivorous fish, *Goramy*.

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# THE EARTHWORMS OF ALLAHABAD.

G E GATES.

EWING COLLEGE, ALLAHABAD.

(Communicated by Prof. B. Sahni, F.R.S.)

(Received 16 September 1944)

## ABSTRACT

Some fifteen thousand odd earthworms of the Allahabad municipal area, including a small trans-Jumna area, obtained in weekly collections during six months and fortnightly collections during the remainder of the year, belong to 19 species of 15 genera in the families Ocnerodrilidae, Megascolecidae and Lumbricidae. Two Ocnerodrilid species certainly have not become well established while *P. houlleti*, *B. albida* and the single Lumbricid were found only rarely.

*Pluteillus exilis*, *Perionyx sansibaricus*, (*Thatonia parva* and *Malabarica* sp.) were found only in soil moistened by waste effluent of human habitations. *Ocnerodrilus tenellulus* and *Dichogaster bolani* were usually found, and in greatest numbers, in the same or similar habitats, as also but with less restriction *R. cultrifera*. *P. posthuma* was found in sandy soil. Saturation of soil with kitchen drainage resulted in replacement of species of *Eutyphoeus* and *Octohastoides beatrix* by *O. tenellulus* and *D. bolani*.

Those species which are able to continue an active existence in restricted areas during the period of drouth are sexual earlier in the year and throughout a much greater portion of the year. Those species which disappear at end of the rains have a short sexual season of two to three months.

## INTRODUCTION

Much of our knowledge of earthworms, throughout many of the more interesting portions of the world, rests on a few small, random collections. Accordingly it is important that intensive surveys, especially of limited areas which can be thoroughly studied, be made whenever opportunity arises. Exigencies of the war, with the interest and initiative of Mr. I. D. Caleb of the Biology Department of this college, have now enabled such an intensive study of the earthworms of Allahabad, from which only three species had been recorded hitherto:—*Eutyphoeus incommodus*, *Pheretima houlleti* and *P. posthuma*. The more important taxonomic data are in course of publication elsewhere. A summary of other results is presented herewith.

Two municipal areas in Asia, both probably of a size similar to that of the Allahabad area, have been studied hitherto. Prashad's report (1916)

indicates that the Lahore municipal area has a pauper fauna of but seven species, all of which are immigrants or importations:—*Lampito mauritii*, *Pheretima diffringens*, *P. hawayana*, *P. morrisi*, *P. posthuma*, *Allolobophora caliginosa* and *Bimastos parvus*.

A report on the earthworms of the Rangoon municipal area (Gates, 1926) dealt only with larger species. Later work revealed a number of small species from habitats previously neglected. A further report on all the Rangoon species, including results of several years work, was lost in manuscript on the fall of Burma. As a complete list of Rangoon species has not been available hitherto such a list has been included alongside the Allahabad species for comparison.

Although the Allahabad survey was continued only through a period of twelve months, experience gained in Rangoon during a number of years, should have enabled greater approximation to completeness, so far as number of species is concerned, than was obtained in the early Rangoon report.

The author's thanks are extended to Mr. A. Brooks for assistance in an attempt to secure information regarding soils and to Mr. Caleb, not only for making this work possible, but also for constant help throughout the whole period in which it was under way.

#### METHODS, DEFINITIONS, ETC.

No easy way is known to the author of procuring earthworms in the numbers and from the varied areas necessary for a survey of the present type, though in peace times chemicals and electricity have some use close to sources of water and electrical supply. Accordingly a mahli, who had shown ability and willingness to carry out instructions as well as some interest in this sort of work, was trained to do the collecting. He was taught to dig up the top six to eight inches of soil (in ordinary soils worms were not found below that depth), break the clods apart, and then pick up all worms from the very smallest size recognizable, as well as cocoons. After a representative collection had been secured from a particular spot, similar collections were made at other spots that for any reason whatever might indicate promise of having a different fauna. In this way collections were made in various quarters, from grassed areas, bare ground under trees, cultivated fields, gardens, dumps, manure heaps, piles of decaying leaves, roadside ditches, banks of drainage ditches, river banks, soils wetted by kitchen drainage, mud at bottom of buffalo wallows, other small pools and the lake, algal mats at bottom of water storage tanks and from dirt around roots of potted plants.

From the first of July (1943) collections were made regularly the first day or the first two days of each week and occasionally on additional days later in the week. Towards the end of the season, at a time when certain species are found crawling around on the surface of the ground early in the morning, such worms were picked up in certain areas every morning. After November, collections were made only at fortnightly intervals, mainly to avoid repetition, or at least too frequent repetition, of digging in a limited number of constantly more restricted areas. At the earliest opportunity after collection worms were taken to the laboratory and preserved. Even so specimens of one species were almost always in poor condition.

In this report three stages are recognized.—(1) Clitellate, with clitellum fully developed or clitellar region indicated by readily recognizable colour or other differences. (2) Aclitellate, with porophores, genital markings, seminal furrows, copulatory structures, etc., readily recognizable but with no indication of a clitellum. (3) Juvenile, including all other forms, from the very smallest just hatched from cocoons. On larger individuals anlage of genital markings, porophores, etc., may be recognizable on careful examination with the binocular and sites of reproductive apertures may be indicated by minute, greyish translucent points or even more definitely pore-like appearances. In a few species post-sexual individuals are distinguishable, at least for a time, from the pre-sexual aclitellate condition but it is not known whether such distinction is temporary or permanent and if the former whether regression can be continued to a condition indistinguishable from that of the larger juveniles.

The area investigated includes the municipal region of Allahabad between the Jumna and Ganges rivers from the confluence to McPherson Park and in addition a trans-Jumna belt along the river from the confluence to west of the Agricultural Institute and south to the Leper Asylum. The trans-Jumna belt is referred to hereinafter as Naini.

Soils of Allahabad are characterized as "Gangetic alluvium" but further information seems to be unavailable, at least locally. One type of soil containing certain species that are not found elsewhere, is described by Mr. Brooks as follows:—"A loam of darker colour than most Allahabad soils with a good deal of well decomposed organic matter, a 'wash-water' odor that suggests ditch or drainage area containing the waste effluent of human habitations, pH of approximately 7.5 not very different from that of many soils in the Allahabad area."

The elevation of Allahabad is said to be 309 feet. The average annual rainfall is 39.52 inches. Figures for average monthly means of air temperature and for average monthly rainfall, from the Indian Year Book, are included in the table.

## ALLAHABAD SPECIES

During the year's survey well over 15,000 specimens were collected, the exact total unknown as large numbers of two species from restricted habitats were not counted. The worms are referable to nineteen species belonging to fifteen genera of three families as listed below. One species is unidentifiable, only immature and abnormal forms having been secured. Another species was represented in the collections by one immature individual. Obviously these Ocnerodrilids are not important constituents of the Allahabad fauna. Included in the list are all but two of the species hitherto recorded from the Benares-Lucknow sector of the Indo-Gangetic plains. Of the two species, *Eutyphæus orientalis* apparently is not present in the Allahabad area. The other, *Glyphodrilus papillatus*, even when present, is often difficult to secure, being usually restricted to less easily accessible portions of muddy bottoms of lakes and ponds. The only Indian record is Lucknow to which the species may have been transported from its presumed home in Burma.

## LIST OF SPECIES

	From Allahabad.	From Rangoon.
OCNERODRILIDÆ		
<i>Thatonia</i>	<i>parva</i>	
<i>Malabaria</i>	<i>sp.</i>	
<i>Eukerria</i>		<i>peguana</i>
<i>Gordiodrilus</i>		<i>peguanus</i>
<i>Ocnerodrilus</i>		<i>occidentalis</i>
	<i>tenellulus</i>	<i>tenellulus</i>
MONILIGASTRIDÆ		
<i>Drawida</i>		<i>gracilis</i>
		<i>longatria</i>
		<i>nana</i>
		<i>peguana</i>
		<i>rangoonensis</i>
		<i>rara</i>

## MEGASCOLECIDÆ

<i>Plutellus</i>	<i>exilis</i>	
		<i>pandus</i>
<i>Perionyx</i>		<i>excavatus</i>
	<i>sansibaricus</i>	
<i>Ramiella</i>	<i>cultrifera</i>	<i>cultrifera</i>
	<i>nainiana</i>	
<i>Eutyphœus</i>		<i>foveatus</i>
	<i>incommodus</i>	
	<i>nicholsoni</i>	
		<i>peguanus</i>
		<i>rarus</i>
	<i>waltoni</i>	
<i>Bahlia</i>	<i>albida</i>	
<i>Octochaetoides</i>	<i>beatrice</i>	
		<i>surensis</i>
<i>Pellogaster</i>	<i>isabellæ</i>	
<i>Lenogaster</i>		<i>chittagongensis</i>
	<i>pusillus</i>	
<i>Dichogaster</i>	<i>bolau</i>	<i>bolau</i>
		<i>modiglianii</i>
<i>Notoscolex</i>		<i>pumila</i>
<i>Lampito</i>	<i>mauritii</i>	<i>mauritii</i>
<i>Pheretima</i>		<i>alexandri</i>
		<i>anomala</i>
		<i>bicincta</i>
		<i>campanulata</i>
		<i>elongata</i>
	<i>houletti</i>	<i>houletti</i>
		<i>humilis</i>
		<i>peguana</i>
		<i>planata</i>
	<i>posthuma</i>	<i>posthuma</i>

## GLOSSOSCOLECIDÆ

<i>Glyphidrilus</i>	<i>papillatus</i>
	<i>sp.</i>
<i>Pontoscolex</i>	<i>corethrurus</i>

## LUMBRICIDÆ

<i>Bimastos</i>	<i>parvus</i>
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## LOCAL DISTRIBUTION

Several species, *T. parva*, *Malabarica* sp., *P. exilis*, *P. sansibaricus*, *B. albida*, *P. houlleti* and *B. parvus*, have been found only in the Allahabad portion of the area investigated. *P. houlleti* has been found mostly in flower pots which were not investigated on the Naini side, an occasional individual only being found along with species of *Eutyphoeus*. *B. albida* has only been secured in very limited numbers, one or two specimens at a time, along with species of *Eutyphoeus*. Further laborious digging, around or near the spots where the first individuals were secured, always failed to yield additional material. As the number of earthworms collected on the Naini side is roughly equivalent to that from the other side, some at least, might have been expected from Naini, if the species is present there. Although *P. sansibaricus* has been collected from several quarters of Allahabad it was never found in Naini, in spite of a number of very careful searches.

*R. nainiana* is found very rarely in the Allahabad section and then only in small numbers, almost all of the specimens of this species having been secured on the Naini side. *L. pusillus* has been found in Allahabad only in flower pots, while *P. isabellae* has not been found in Allahabad at all.

## HABITATS

Most distinctive, so far as its earthworms are concerned, is the soil of the drainage ditches which has been characterized above. Such soil may be called the *sansibaricus* habitat as that species has not been found elsewhere. *P. exilis*, *T. parva* and *Malabarica* sp., also have not been found elsewhere but have been secured only from certain drains in the Daraganj quarter. March, August and one of the January specimens of *B. parvus* were also secured from the same Daraganj drains. In the *sansibaricus* habitat there have also been found regularly and in considerable numbers the following species: *O. tenellulus*, *R. cultrifera* and *D. bolau*i. Of these the last-named has only rarely been found elsewhere. Other species have been found elsewhere, as indicated below, usually in habitats where the percentage of organic matter is higher than in ordinary soil. Very rarely an isolated specimen or two of *O. tenellulus* has been found in ordinary soil along with *R. nainiana*, *P. isabellae*, or species of *Eutyphoeus*. More frequently *R. cultrifera* has been found with the species just mentioned, and especially along with *R. nainiana* and *P. isabellae*.

*P. posthuma* was nearly always obtainable in two widely separated localities, one in Naini, the other near McPherson Park in Allahabad. These

are near the Jumna and the Ganges Rivers and the soil obviously contains a much higher percentage of sand than usual. Material secured from these two sources, in July and October at least, is not included in the table, the few specimens listed for September-October having been secured from another spot, some distance from either of the rivers where the soil is at least somewhat more sandy than usual. With the drying up of the ground at close of the rainy season the sources from which material can be secured approximate more and more to the *sansibaricus* and *posthuma* habitats.

Other habitats and their faunae are shown below.

Municipal dump, Leader Street : *O. tenellulus* ; *R. cultrifera*

Manure heap, Ewing College : (October) *E. nicholsoni*, 0-0-12 ; *E. waltoni*, 0-0-16 ; *L. mauriti*, 46-18-3 ; *P. posthuma*, 0-0-1.

The history of this heap is unknown. Specimens of the two species of *Eutyphoeus* obtained here were much larger than from any other locality.

Flower pots : *E. waltoni* ; *E. nicholsoni* ; *O. beatrix* ; *L. pusillus* ; *L. mauriti* ; *P. houlleti*.

These pots were resting directly on the ground from which there was access to the interior of the pots through bottom holes. Included here are most of the larger pots. Pots isolated from the ground by bricks or stones, or resting on masonry work, verandahs, etc., and at a distance of two to eight feet from the ground, usually of smaller size, contained the species listed below.

Flower pots. (Smaller and isolated from the ground) : *L. pusillus* ; *D. bolau* ; *P. houlleti* ; *B. parvus*.

Algal mats at bottom of water tank, *O. tenellulus*.

Bath tub in college house, *D. bolau*.

The tub is a built-in, concrete structure from the bottom of which, near one end, a pipe runs to the outside, projecting about six inches from the wall and about a foot above the ground, and from which the water falls into an open concrete drain. Ordinarily the tub is kept full of water, but if after being emptied, the tub is not refilled, the worms appeared (July to September).

In a bundle of "pan" leaves (*Piper betle*) purchased in the bazaar there was found an acitellate specimen of *D. bolau*.

Change in character of soil may result in change of earthworm fauna. A fortunate opportunity to check on one such change was accidentally provided by the plugging of an underground drain from a kitchen. The plugged drain was replaced by a surface drain which allowed water from the kitchen sink to run on to soil which in the previous year had contained only species of *Eutyphoeus* and an occasional specimen of *O. beatrix* and *L. mauritii*. After some months the soil moistened by the kitchen drainage was dug up. Only *O. tenellulus* and *D. bolawi* were found. Clitellate specimens of the latter are much larger than any previously seen by the author.

#### SEASONAL OCCURRENCE

Allahabad is in monsoon country and is commonly said to have three seasons: (1) a rainy season (June or July to September or October), the dry portion of the year divided according to temperature into (2) cold and (3) hot seasons. The new year for earthworms in Allahabad accordingly begins in July, when the monsoon rainfall has sufficiently moistened the soil to enable normal activity near the surface. The appearance of the worms is not as dramatic as has been noted in certain parts of Burma but more gradual.

In October-November the worms begin to disappear. From the middle of November and during December a few individuals could still be collected in isolated spots that had been well shaded or protected by various accidents from the effects of the drouth. After the first of January collecting had to be restricted to banks of drainage ditches, small spots kept moist by kitchen drainage, seepage or leakage from taps, pipes, etc. In May earthworms could still be obtained from banks of drainage ditches in the Daraganj quarter and in a small area near the outlet of McPherson Lake kept moist by seepage from the lake. From both of these localities worms had completely disappeared early in June, the only specimens collected during that month being found between joints of a pipe, under water, near the opening into one of the Daraganj ditches. The same results were obtained in June of the previous year (1943). No attempt was made in June to secure worms from flower pots or from any gardens that might have been fairly well watered.

Reference to the table will show that the time of disappearance is not uniform but varies according to the species. Thus *H. nainiana*, *P. isabellae*, *L. pusillus* and *B. albida* (with one exception noted below) were not found after the first of November. The three species of *Eutyphoeus* were obtainable throughout October and November but with constantly increasing difficulty and (except for isolated individuals) were not found after the first week of December.

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TABLE

Species.	July	August	September.	October.	November
<i>T. parva</i> ...	...	...	0-1-0	...	...
<i>Malabarica</i> sp. ...	...	...	90-12-0	...	...
<i>O. tenellulus</i> ...	1-3-392	10-0-4	0-47-247	0 0-55	0-0-22
<i>P. exilis.</i> ...	0-3-0	...	89-0-0	...	47-29-7
<i>P. sansibaricus</i> ...	+	+	+	+	+
<i>R. cultrifera</i> ...	0-1-111	16-305-265	1-313-17	0-6-0	117-0
<i>R. nainiana.</i> ...	140-37-0	1009-331-320	60-175-503	0-2-412	0-1-171
<i>E. incommodus</i> ...	131-18-7	160-202-93	42-43-278	0 1-18	0-0-11
<i>E. nicholsoni</i> ..	18-0-0	7-134-34	12-13-161	0-0-157	0-0-46
<i>E. waltoni</i> ..	262-0-0	470-716-110	0-14-463	0-0-303	0-0-36
<i>B. albida</i> ...	5-1-0	30-4-5	28-2-2	1-0-0	...
<i>O. beatrix</i> ...	3-0-0	5-12-19	0-1-14	0 1-2	0-0-5
<i>P. isabellae</i> ...	20-10-0	200-201-25	22-10-4	0-4-0	...
<i>L. pusillus</i> ...	0-0-8	0-23-131	0-1-70	0-0-2	.
<i>D. bolani</i> .	0-0-7	0-3-24	37-27-158	125-173	14-6-10
<i>L. mauritii</i> ...	+ + -13	116-18-65	66-61-39	80-79-2	50-28-11
<i>P. houlleti</i> ...	0-5-5	0-0-1	.	0-0-14	...
<i>P. posthuma</i> .	+	+	0-0-2	0-0-1	2-6-43
<i>B. parvus</i> .	..	1-0-1	...	..	..
Rainfall ...	12 24	10.88	6.32	2.40	0.25
Temperature ...	84.5	83.2	83	77.6	67 5

The first in each set of figures indicates number of juvenile, the second acitellate, and the third clitellate specimens. When there are only two figures, the first includes both juvenile and acitellate specimens.

Banks of the drainage ditch from which the specimens of *T. parva* and *M. sp.*, were secured were flooded during parts of July and August and later were bricked over. A num-

TABLE

December.	January.	February.	March.	April.	May.	June.
..	...	...	...	..	.	...
...	...	...	...	...	..	...
0-210-192	0-0-4	0-16-9	0-0-46	0-2-130	0-0-7	0-3-38
153-150 42	0-7-37	0-16-2	0-0-1	0-60-1	..	...
+	+	+	+	+	+	+
	..	18-17-0	..	..	0-5-41	..
.	.	..	...	...	.	...
0-0-13	..	0-0-1	.	...	1-0-2	..
0-0-2	...	..	...	.	1-0-0	...
	.	...	.	1-0-0	.	...
..	..	..	..	2-0-0	...	...
0 0-2	..	3-0-0	..	4-0-0	3-0 1	...
.	.	.	..	..	.	...
..	..	...	..	...	.	...
4-48-66	50-23-20	70-40-38	4-0-41	5-4-82	0-1-7	...
10-16-2	...	1-0-0	...	..	...	...
..	...	...	...	..	...	...
8-6-45	+	0-0-13	+	+	9-0-13	...
	0-1 8	...	0-0-2	.	...	...
0.23	0.82	0.48	0.38	0.14	0.29	5.09
59.8	59.5	64.9	76.8	87.6	92.5	90.8

ber of careful searches for these two species in nearby localities were all failures. (Progress of civilization versus advance of science!)

With one exception July specimens of *P. heulsteti* were from pets as were all October specimens.

*L. mauritii* was not found after the end of February. Although *R. cultrifera* and *O. beatrix* were not secured in two more months, their collection in May presumably indicates that more extensive search would have found them in the other months. *P. exilis* was not found after April (absence of records in early portions of the season due to flooding) By the middle of May only *O. tenellulus*, *P. sansibaricus*, *P. posthuma*, and *D. bolau*i were obtainable and by the middle of June the only species that could be found, in drain-pipe joints under water, were *O. tenellulus* and *P. sansibaricus*.

#### NOTES ON LIFE HISTORY

Early even in July, *O. tene'lulus*, *P. sansibaricus*, *R. cultrifera*, *D. bolau*i, *L. mauritii*, *P. houlleti* and *P. posthuma* were found not only in clitellate but in fully sexual condition. This is shown by brilliant spermatozoal iridescence on the male funnels (*O. tenellulus*) and also (other species) in the spermathecal diverticula, the latter indicating that copulation had taken place. Of these species *O. tenellulus*, *P. sansibaricus*, *R. cultrifera* and *D. bolau*i have been found in sexual condition as late as the first week of May. *O. beatrix* and *L. mauritii* have been found in sexual condition in December, *P. houlleti* in January (1943), *B. parvus* in March, *P. exilis* in the period from November to April. Failure to find sexual, or even clitellate specimens of *P. exilis* during the rainy season months probably is of no special significance. Localities from which the clitellate specimens were later secured were flooded at times of collecting during rainy season months.

There is no intention to suggest that any particular individual is or remains sexual throughout all of the period in which sexual forms have been found. In fact all of the little evidence available indicates the contrary. Obviously postsexual ac clitellate individuals of *L. mauritii* were found in October-December, and of *P. sansibaricus* throughout the period from August to May. Possibly postsexual ac clitellate specimens of *D. bolau*i have been found from September to May. Several specimens of *E. incommodus* collected early in July have a marked brownish discoloration of clitellar segments though the epidermis of those segments is certainly no thicker than elsewhere. Genital markings are barely recognizable and at most demarcation between central area and rim is only faintly indicated. These specimens would appear to be survivors from the previous year in which the genital markings, as well as the clitellum, have regressed but not so completely as to be unrecognizable.

Other species do not become sexual as early in the season. A few clitellate specimens of *E. incommodus* were secured in the last week of July but sexual specimens were not obtained until the first week of August. Not

until August 9 were there recognizable first indications of development of a clitellum in *E. waltoni*, *R. nainiana* and *P. isabellae*, but fully clitellate and sexual specimens of these three species were not obtained until August 16. The first clitellate specimen of *E. nicholsoni* was found August 26 as was the first clitellate specimen of *B. albida*. A sexual specimen of the latter species had however been secured two weeks previously at Mirzapur. As the season progresses the percentages of juvenile and aclitellate specimens drop to or almost to zero. Copulation continued in two species, *nicholsoni* and *waltoni*, into November. In the latter month some of the specimens brought into the laboratory were actually copulating in the middle of a clump of mixed species of earthworms in the collector's pail. Such copulating pairs could be handled fairly roughly without inducing separation.

Cocoons of most species have not been found, nor have just hatched juveniles of any species of *Eutyphoeus* been secured. Cocoons of two species, *P. posthuma* and *P. sansibaricus*, have been collected. These have been found in soil up to the first week of March but cocoons of *sansibaricus* have been deposited in the laboratory as late as March 28.

As the soil begins to dry out at the close of the rainy season in October-November (September in 1944), clitellate specimens of *E. nicholsoni* and *waltoni* are found early in the morning wandering about aimlessly until they are dried up by the heat of the sun. The numbers of these two species found in limited localities are such as to indicate that considerable percentages of adult populations are lost in this manner. Other species have not been found in this way, though after a very heavy rain an occasional specimen of *E. incommodus*, as well as of the other two species of *Eutyphoeus*, has been found wandering about near standing water.

Sooner or later, according to species and condition of the soil, earthworms disappear from the upper layer of the soil in which they have hitherto been found. Where they go and what may be the conditions of their existence during the remainder of the year, a period of two to seven months, is unknown. At present it seems reasonable to assume that such adults as survive go deeper into the ground where they presumably enter a period of considerably reduced metabolic activity. As this period coincides, for some species, with both cold and hot seasons, neither "hibernation" nor "aestivation" seems to be applicable. An adequate term would have to indicate correlation of periods of activity and inactivity with rainy and dry seasons.

In some few cases at least, the period of inactivity may be spent in the same upper layer of soil in which the worm is active during the rainy season. Late in April a small plot of ground was dug up to a depth of eight inches. This plot was within an area which had contained during the rains three species of *Eutyphoeus* and an occasional specimen of *O. beatrix*. None of these were found in the April digging but on carefully breaking apart the clods, two quiescent juvenile specimens of *B. albidus* were found. Each was coiled up in a small, closed chamber one to three inches below the surface. Although major blood vessels were visible through the body wall and obviously red there was no recognizable indication of circulation of blood. The worms, though exposed to the mid-day heat and even direct rays of the sun remained motionless. When dropped into water each worm at once uncoiled but after several convulsive movements again became motionless.

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# ON THE OCCURRENCE OF *NEOTIELLA CATHARINAEA* McLENNAN AND HALSEY

(With one plate)

BY S. N. DAS GUPTA AND T. S. SADASIVAN

DEPARTMENT OF BOTANY, LUCKNOW UNIVERSITY, LUCKNOW

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## ABSTRACT

A pezizaceous fungus, occurring in the axils of the leaves of *Catharinaea Mulleri* Hamp. et C. Müll., has been collected from the western and eastern Himalayas at altitudes of 7,500 and 4,000 ft. respectively. It has been found to be identical with *Neotiella Catharinaea* McLennan and Halsey collected by them from Kallista and Ferntree Gully, Victoria (Australia). Some observations on the distribution and the habit of the fungus have also been included.

A pezizaceous fungus *Neotiella Catharinaea* McLennan and Halsey, occurring in the axils of the leaves of the moss *Catharinaea Mülleri* Hamp. et C. Müll. was collected by the senior author near Khati at an altitude of about 7,500 ft. in the Western Himalayas during a botanical trip to Pindari glaciers in October 1936. Subsequent collections of the fungus were made beyond Munsyari (eastern side of Western Himalayas) at almost the same height on way to Milam glaciers in October 1937, and at Mungpoo (Darjeeling, Eastern Himalayas) in 1938 at an altitude of 4,000 ft.

The characteristics of *Neotiella Catharinaea* collected from these places are identical with those of the type species described by McLennan and Halsey (1936, p. 57). Preserved specimens of *Neotiella Catharinaea* which were kindly sent to us by Dr. E. McLennan from Melbourne were also compared with our specimen and was found to agree in all respects except that the external clothing of hair is denser in the specimen sent to us. The moss was identified as *Catharinaea Mülleri* Hamp et C. Müll. from an authentic specimen kindly supplied by Dr. S. K. Pande from his collection and the capsule of the moss sent by Dr. McLennan. The apothecia grow in the axils of the moss *Catharinaea Mulleri* (Pl. 1, figs. 1 and 2) and sometimes on its base attached to the rhizoids. They are orange in colour usually solitary and laterally attached; sometimes two apothecia may be terminally attached (Pl. 1, fig 6).

The fungus is anchored to the moss plant by means of thick-walled septate hairs gradually tapering, branched or unbranched and varying in

diameter at the tips (Pl. 1, fig. 5), which clothe the entire outer surface of the fungus together with a little amount of soil and humus, and kept in position by means of adpressed leaves. Examination of teased and microtome preparations failed to reveal any special device for attachment.

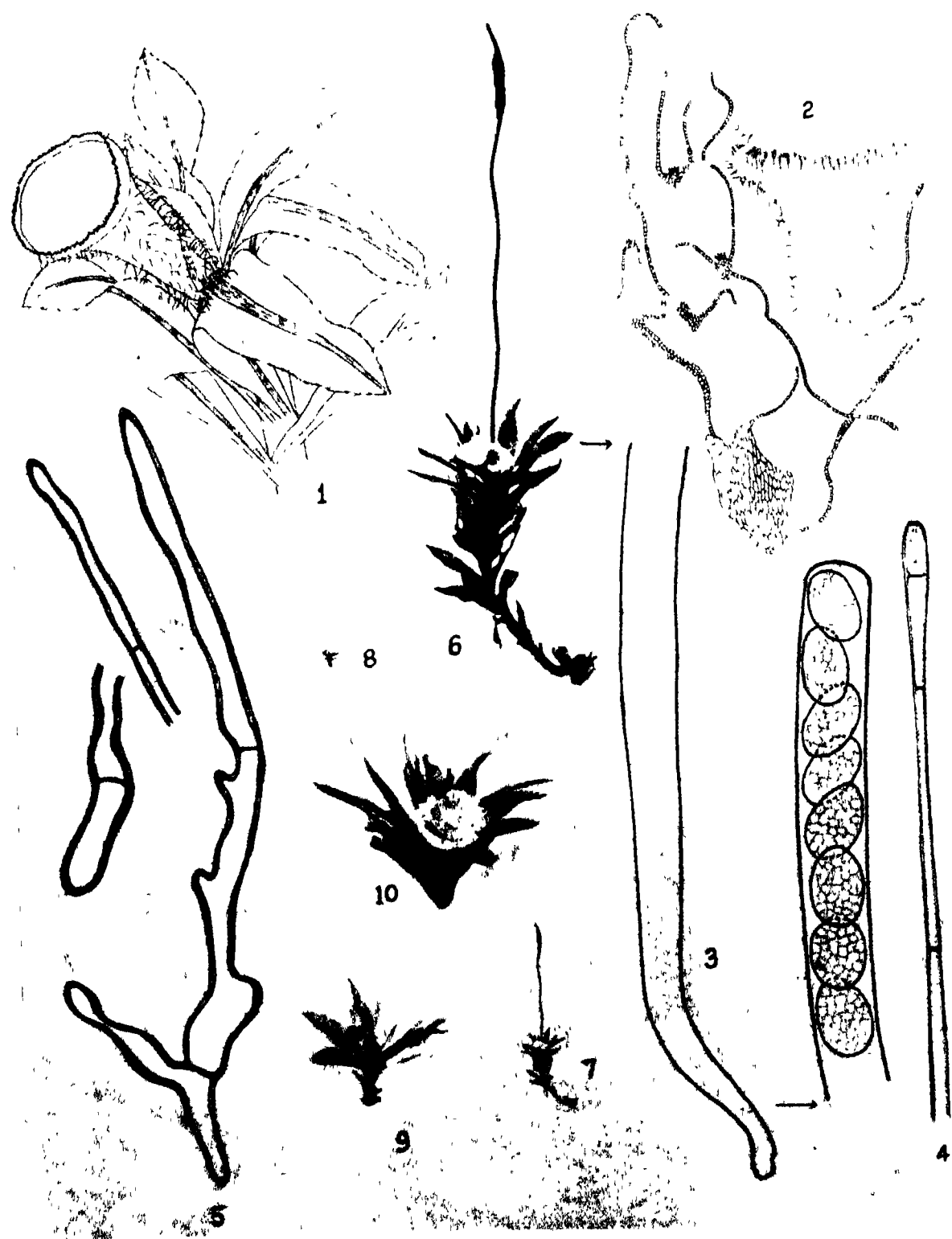
In order to find out if *Neotiella Catharinaea* occurs on any other moss plant a thorough search was made in the neighbouring areas, but the fungus was not found on any other species. One apothecium was found attached to a protonema apparently of *Catharinaea Mülleri* and a few others on the soil in the midst of younger plants of the species, but it is doubtful if these were directly growing on the soil. In two specimens the apothecium while mainly attached to the axils of moss leaves showed partial attachment to a leafy *Jungermanniales* in one case and to *Targionia hypophylla* in the other.

McLennan and Halsey (1936) collected *Neotiella Catharinaea* from Kallista and Ferntree Gully, Victoria (Australia). The Gully is situated some 24 miles from Melbourne in a range of low mountains called Dandenong Ranges with an elevation of 1,500 ft. Our collections from near Khati (Pindari route) and from beyond Munsyari (Milam route) and Mungpoo (Darjeeling) indicate that in the Western Himalayas the fungus is distributed at an altitude of over 7,000 ft. and in the Eastern Himalayas at an altitude of about 4,000 ft. The occurrence of the same fungus on the identical moss plant in two completely isolated regions, the Himalayan Range in India and the Dandenong Ranges in Australia separated by high seas is interesting from the point of view of distribution of the species. It would be interesting to find out if *Neotiella Catharinaea* is also distributed further east in Assam Himalayas and in the hill ranges of Malaya and Pacific islands.

*Neotiella Catharinaea* was exclusively found on *Catharinaea Mülleri*. There were other species of moss directly adjoining the area occupied by *Catharinaea Mülleri* which are able to afford equally good harbour for the *Neotiella* spores, but none of these had *Neotiella* growing on them. The host range of the fungus is thus strictly limited to a single species of moss which is suggestive of a definite relationship existing between the two. Attempts to find out the true nature of the relationship by examining microtome sections of the entire moss plant with the attached fungus failed to reveal any internal hypha nor were there any modifications of the external hyphae to derive nourishment from the host. The fungus apparently resides epiphytically on the moss and is not an ectoparasite like *Neotiella Crozalsiana* Grélet. on *Plagiochila asplenioides* (L.) Dum., described by Corner (1929). It derives its nourishment from the organic matter present in the soil with which it is associated in the axils of moss leaves.







In a few cases the hyphae were found to be firmly adpressed on the moss leaves along the midrib. It was found, however, as already indicated, that the contact is superficial and the hyphae do not penetrate the cells neither do they form haustoria. Nevertheless, it is not unlikely that the fungus in such cases derives a part of its nourishment from the conducting channel by means of osmosis; the high osmotic pressure possessed by the fungal cells being well known.

Our thanks are due to Dr. E. McLennan, for very kindly sending us specimens of *Neotiella Catharinaea* and capsules of *Catharinaea Mülleri* Hamp. et C. Müll. which were of great help for comparing with our material and also for her confirmation of our identification. We also thank Dr. S. K. Pande for helping us in the identification of the moss.

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- Corner, E. J. H. (1929) A Humariaceous fungus parasitic on a Liverwort *Ann. Bot.*, **43**, 491-505.
- McLennan, E. and Halsey, F. (1936). Additions to the Australian Ascomycetes, No 3, *Proc. Roy. Soc., Victoria*, **42** (N. S.). (1).

#### EXPLANATION OF PLATE

Figs 1-5. Camera lucida sketches of *Neotiella Catharinaea* McLennan and Halsey on *Catharinaea Mülleri* Hamp. et C. Müll.

1. Showing position of apothecium in the axil of leaf of moss.
2. L. S. entire moss with the fungus attached; the adpressed leaves serve to keep the fungus in position x 21.
3. Ascus with 8 ascospores. x 680.
4. Paraphysis x 680.
5. Hairs which serve to anchor the fungus. x 680.

Figs 6-10. Photographs of *Neotiella Catharinaea* McLennan and Halsey on *Catharinaea Mülleri* Hamp. et C. Müll.

6. Two terminal apothecia of *Neotiella Catharinaea* on the moss *Catharinaea Mülleri* with the capsule. x 3.5.
7. The same as above (natural size).
8. Another specimen of *Neotiella Catharinaea* on *Catharinaea Mülleri* showing lateral attachment of apothecium (natural size).
9. Same as above magnified x 3.5.
10. Showing laterally attached apothecium of *Neotiella Catharinaea* lying in a rosette of leaves of moss. x 5.



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# SOME MESOZOIC FERNS FROM THE SALT RANGE, PUNJAB

BY

B. SAHNI, SC.D., F.R.S. AND R. V. SITHOLEY, PH.D.

UNIVERSITY OF LUCKNOW.

(With 6 plates)

(Received 2 February 1945)

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## ABSTRACT

Some fossil ferns collected by Mr. E. R. Gee of the Geological Survey of India, Calcutta, from two localities in the Upper Gondwana beds of the Salt Range are described. Most of the specimens are preserved in the form of "compressions". Some of them are fertile and beautifully preserved; they have yielded excellent transfer preparations showing the structure of the sporangia and the spores. The genus *Phlebopteris* is recorded for the first time from the Indian strata with two new species, *P. hirsuta* and *P. indica*. A few sterile specimens have been provisionally assigned to the form-genus *Cladophlebis*: these also may be fragments of *Phlebopteris* leaves but in the sterile condition their exact affinities must remain an open question.

The evidence of the fossils tends to confirm the Jurassic age of the strata.

## INTRODUCTION

The material here described was collected by Mr. E. R. Gee of the Geological Survey of India and was sent to one of us for description by the Director of the Survey to whom we wish to offer our sincere thanks.

The specimens are mostly in the form of compressions and have in some cases yielded excellent transfer preparations and spores.

The fossils come from a horizon "near the top of the Jurassic sequence as represented around Sakesar." They were collected from two localities which, with the names of the species obtained from each, are given below.

*Locality A.* "Tributary 600 Yds. E. of pt. 3920 about 1½ miles, N.E. of Sakesar, Salt Range, Punjab (Sheet 38 P/14)." *Phlebopteris hirsuta* sp. nov., *Phlebopteris indica* sp. nov., *Cladophlebis* (?*Phlebopteris*) sp. A, *Cladophlebis* (?*Phlebopteris*) sp. B

*Locality B.* "In Nala N.E. of Sakesar, Salt Range, Punjab (Sheet 38 P/14)." *Phlebopteris indica* sp. nov., *Cladophlebis* (?*Phlebopteris*) sp. C.

Our knowledge of the Upper Gondwana flora of the Salt Range is extremely meagre. The genus *Phlebopteris* is now recorded for the first time from India.

#### PREVIOUS RECORDS OF JURASSIC PLANTS FROM THIS AREA

The only fossil plants from the Jurassic beds of the Salt Range of which we have any knowledge are few and badly preserved.

In 1880 O Feistmantel (pp. 64-65), in a brief note without figures, mentioned a few plant fragments collected by A. B. Wynne at Shekh Budin. These were preserved 'in a fine, slightly micaceous shale, of a light purplish-grey colour'. The only forms recognisable with any certainty were referred to *Ptilophyllum* (?) *acutifolium* Morr. and *Podozamites lanceolatus* var. *eichwaldi* Heer. Feistmantel added that although this was very unsatisfactory palaeontological evidence, it indicated that the plant-bearing beds at Shekh Budin 'would have to be considered as representatives of the Gondwanas in the Upper Punjab in association with marine beds—a case like that in Kach and on the south-east coast of India'.

Among the old collections at the British Museum one of us (B.S.) examined in 1930 some fragmentary leaf impressions registered as V. 20196-7 and labelled '*Pecopteris*'. The locality was given as 'Moosakhel (Jurassic)'. These would appear to be the same fossils as the ones referred to by Waagen in a note on the Attock slates (1879, Vol 12, p. 184), where he says that they belonged to a collection of the Geological Society of London. We know from Mr. W. N. Edwards, now Keeper of Geology at the British Museum, that the Geological Society's collections were later

transferred to that museum. Our thanks are due to Mr. Edwards for permission to examine these fossils.

#### DESCRIPTION

Among Mr. Gee's specimens we have provisionally been able to recognise five distinct forms, two of which are fertile and the rest sterile. These are:—

##### FERTILE SPECIMENS

*Phlebopteris hirsuta* sp. nov.

Locality A—Nos. K35/98, K35/124, K35/133 (counterparts). (Pls. 1-2.)

*Phlebopteris indica* sp. nov.

Locality A—Nos. K35/243, K35/392. (Pl. 4, figs. 22-24; Pl. 5, figs. 25-26.)

Locality B—Nos. K35/532, K35/537 (counterparts), K35/491. (Pl. 3; Pl. 4, figs. 18-21.)

##### STERILE SPECIMENS

*Cladophlebis* (?*Phlebopteris*) sp. A.

Locality A—Nos. K35/111, K35/376. (Pl. 5, figs. 27-30.)

*Cladophlebis* (*Phlebopteris*) sp. B.

Locality A—No. K35/358. (Pl. 6, figs. 33-34.)

*Cladophlebis* (?*Phlebopteris*) sp. C.

Locality B—No. K35/554. (Pl. 6, figs. 35-36.)

The locality and number of one specimen (Pl. 6, fig. 37) cannot be ascertained.

Genus *Phlebopteris* (Brongn.) Hirmer and Hoermammer emend.

We have assigned to two new species of *Phlebopteris* Brongn. some well preserved specimens shown in Pls. 1-5. Although these small fragments convey no idea of the habit of the frond, the form of the pinnules combined with the soral characters suffices to show their affinity with the Matoniaceae.

Until recently such specimens were freely referred to the old and familiar genus *Lacopteris* of Presl (see Sternberg, 1838, p.115). But in a monograph of the fossil and recent Matoniaceae, published in 1936, Hirmer and Hoermhammer (pp.8-7) have given reasons against the employment of this generic name for fossil Matoniaceous leaves. After a careful examination of the type specimen labelled '*Lacopteris elegans*' Presl, which is preserved at Munich, these authors conclude that the specimen is too badly preserved, and probably was always too badly preserved, to give any idea of its real affinities. In fact they are inclined to remove it altogether from the list of type specimens.



In any case it is obvious that this old specimen cannot possibly have belonged to a Matoniaceous fern. In the photographs of the fossil published by Hirmer and Hoerhammer (1936, figs. 1, 1a, p. 4) the pinnule is seen attached to the rachis by a distinct stalk. This fact alone would seem to rule out any close affinity with the genus *Matonia* in which the pinnules are always attached by the full width of the base. The venation cannot be made out in Presl's type specimen, and if Presl's sketch for the veins, reproduced in Hirmer and Hoerhammer's text-fig. 1 (2, 2a) is correct, the fossil cannot be referred to the Matoniaceae. Nor are the sori at all clearly preserved and, as the German authors say, even Presl's own figure of the sorus seems to recall the sorus of a Marattiaceous fern like *Kaulfussia* rather than that of *Matonia*.

For these reasons we agree that the name *Laccopteris*, although so familiar and established by long usage, cannot correctly be used for describing fossil leaves of known Matoniaceous affinity.

For fossil Matoniaceous leaves Hirmer and Hoerhammer have revived the genus *Phlebopteris* of Brongniart (1828). It is true that not all species referred to this genus by Brongniart belong to this family: the genus as first used by the French author was an artificial group including more than one family of ferns. But, as Hirmer and Hoerhammer point out, the first specimen described under it, namely, *Phlebopteris polypodioides* Brongn. (1828, Pl. 83, figs. 1, 1a), was an undoubted member of the Matoniaceae. This is evident from the characteristic venation of the pinnules, which show a series of larger areoles on either side of the median vein and are attached to the winged rachis by the full width of the base. The genus *Phlebopteris* may, therefore, be accepted as the type genus of this family of ferns, and *Phlebopteris polypodioides* Brongn. as the type species of the genus.

Both our new species recall in general characters *Phlebopteris muensteri* Schenk sp. but differ in several well marked features.

*Phlebopteris hirsuta* sp. nov.

(Pls. 1 and 2)

**Diagnosis:**—*Habit of frond unknown. Pinnules falcate, ca. 5-10 mm. long, attached directly to the rachis by a slightly expanded base about 2 mm. wide. Midrib prominent, margins strongly rolled back, partially covering the sori; veins not visible on the surface (? deeply embedded). Rachis and pinnules bear stiff brown multi-cellular hairs. Sori circular, about a dozen on either side of the midrib of each pinnule; the basal sori larger with about 8 annulate sporangia, the distal smaller with fewer sporangia. Spores smooth, 50 $\mu$  to 60 $\mu$ .*

from one apex of the tetrahedron to the opposite base, wall thick ( $8\mu$  to  $10\mu$  at the corners,  $2\mu$  to  $6\mu$  at other places).

Type specimen at the Geological Survey of India, Calcutta, in three pieces (K35/98, K35/124, and K35/133) which are counterparts of one specimen.

The Salt Range specimen comes nearest to *Phlebopteris muensteri* Schenk sp., but is undoubtedly a distinct and new species.

Although our material is scanty and no description of the habit can be given, the specimen is fertile and well preserved. Figs 1 and 2 show the two counterparts of a pinnate fragment which evidently represents the distal part of a ray where the pinnules are always shorter, more closely set, and more inclined to be falcate. In the figured specimens of *P. muensteri* the apical parts of the ray are not shown, so that a fair comparison is not possible. But even after allowing for this fact the two species appear quite distinct. The most striking point of difference from *P. muensteri* and, in fact, from all known species of the genus (as figured in Hirmer and Hoerhammer's monograph) lies in the form of the pinnules. In most species the pinnules are long and strap-shaped, with parallel sides, and bear two parallel series of equal-sized sori. In the Salt Range species (fig.3) the pinnules are more tapering and the broader basal part bears larger sori (each with 8 or 9 sporangia) than the narrower distal regions. The result is that the two rows of sori like the margins of the pinnule, are not parallel but converge towards the tip of each pinnule.

Other features of the species are the prominent midrib (figs. 3, 4), the strongly reflexed margins of the lamina (marked M) which partially conceal the sori, somewhat like the linear indusium of a *Pteris*; and the coarse brown multicellular hairs (fig.5), usually pointed backwards, on the rachis as well as on the pinnules.

On either side of the rachis there are (in a few places only) traces of a narrow web connecting the expanded bases of adjacent pinnules, but as a rule the rachis is not winged.

The venation cannot be made out: it appears that the veins were deeply embedded. All attempts to show up the veins in cuticular preparations have failed.

A carbonised crust is present, but maceration with Schulze's mixture, even with dilute acid, or with the much milder treatment with weak hydrochloric acid and no alkali (recently followed by Harris, 1940, p. 713) left

behind no trace of the cuticle. In Eau de Javel the fragments of crust turned brown but after washing no trace of the cuticle was left. Owing to their delicate nature, fern cuticles are known to be difficult objects for showing up by maceration. Schulze's mixture, however, gave good results with the sporangia and spores. It has not been possible to make any preparation of the sporangium wall which shows the cell structure well, but the spores have been obtained in a large number and in an excellent state of preservation.

The sori are circular (figs. 4 and 6) with a well formed depression in the centre, showing that the plant is a true *Phlebopteris* (old *Lacopteris*) and not a *Matonidium* (cf. diagrams in Hirmer and Hoerhammer, text-fig. 6, p. 45). The annuli are rather regularly arranged, giving a symmetrical appearance to the entire sorus.

The entire contents of a sporangium were taken out intact in the spore mass shown in fig. 7. The photograph shows a part of the sporangium wall (w) still attached to the spores.

The spores are tetrahedral and smooth, as in all known *Matoniaceae*, living and fossil (figs. 7-9). Those of *Matonia pectinata* and *Phlebopteris* (formerly *Lacopteris*) *muensteri* were figured by Zeiller in 1885 (p. 24, figs. l and m); those of *Phlebopteris muensteri* by Hirmer and Hoerhammer (1936, Pl. 5, figs. 5a, 5b). In 1926 Harris (p. 63, fig. 6d) figured the spores of *Phlebopteris* (*Lacopteris*) *groenlandica* Harr. a form which Hirmer and Hoerhammer have incorporated in *P. muensteri*; and in 1921 those of *Phlebopteris angustiloba* (Presl) (Harris, 1931, Pl. 14, fig. 6).

The spores of the Indian species are distinct from all these in having a wall as thick as  $2\mu$  to  $6\mu$  with special thickenings ( $8\mu$ — $10\mu$ ) at the four corners. The triradiate dehiscence slit is, as usual, very clearly seen (fig. 9). In size the great majority of our spores are comparable with those of *Matonia pectinata* (fig. 10) viz.,  $50\mu$ — $60\mu$  from one angle of the tetrahedron to the middle of the opposite base. Some other spores, taken from sporangia on the same fossil leaf, are slightly smaller (about  $40\mu$ ) and have thinner walls, without any corner thickenings (fig. 11). These appear to be immature spores.

*Phlebopteris indica* sp. nov.

(Pl. 3; Pl. 4; Pl. 5, figs. 25-26)

**Diagnosis.**—*Habit unknown. Pinnules falcate, ca. 5-8 mm. long, attached to the rachis by an unexpanded base well under 2 mm. wide; apex broadly rounded, about 1 mm. wide. Midrib prominent, margins strongly rolled back,*

partially covering the sori. Venation strongly marked, furcate; veins somewhat distant, arising from the midrib almost at right angles and forking rather widely. Ramentum not seen. Sori circular, about 6 to 9 on either side of the midrib, uniform in size; each sorus with 5 to 6, rarely 7 sporangia. Spores smooth, ca.  $64\mu$  to  $68\mu$  from one apex of the tetrahedron to the opposite base, wall thick (ca.  $8\mu$  at the corners,  $4\mu$  at other places).

*Type specimen*, K36/491 at the Geological Survey of India, Calcutta.

Differing from *P. hirsuta* in several characters are five small fertile fragments which we believe can be referred to another new species of the genus.

*Specimens* K35/491, K35/532, K35/537

(Pl. 3; Pl. 4, figs. 18-21)

We shall first describe the three best preserved specimens, viz., Nos. K35/491, K35/532, and K35/537. Fig. 12 shows the upper side of the pinna numbered K35/491. This fragment was made into the transfer preparation shown in Pl. 4, fig. 18. The transfer gives a very good view of the lower side of the pinnules and of the sporangia borne on them.

The midrib is strongly marked, as in the previous species, and the margin of the lamina, too, is strongly rolled back; this is shown very clearly by the transfer preparation (fig. 18). But the pinnules, although again falcate, are here shorter (5-6 mm. long), with a bluntly rounded apex fully 1 mm. wide, while the base is well under 2 mm. wide and not appreciably expanded at its attachment to the rachis. The result is that, unlike the condition in *Phlebopteris hirsuta*, the pinnules taper only very gradually to the apex.

Another point of difference is that no trace of ramental hairs has been found.

The most obvious point of distinction from *P. hirsuta*, however, apart from the form of the pinnules, is the venation which is here strongly marked (see figs. 12-16). The veins are short, never more than once forked, rather distantly spaced, and come off at a wide angle (nearly  $90^\circ$ ) from the midrib. The veins fork somewhat widely. We regard these facts as constituting a substantial point of difference, and not one due to a difference in the mode of preservation, because although both the types are represented by fertile pinnules in the same stratum, the veins are strongly marked in the present form and quite invisible on the surface in *Phlebopteris hirsuta*.

The sori (figs. 18-19) are here more uniform in size, each containing as a rule only 5 or 6 sporangia, rarely as many as 7. Thus on the whole the sori

have fewer sporangia than in *P. hirsuta*. As in that species, there is a well formed depression in the centre of each sorus.

The spores (figs. 20-21) are smooth walled, as in all Matoniaceae, recent and fossil, the size being *ca* 64 $\mu$ -68 $\mu$  which is somewhat larger than in *P. hirsuta*. Fig. 21 shows a dehiscid spore by the side of a deformed one.

It has been possible to obtain by maceration a few fragments of the cuticle of the lamina. Fig. 17 shows one of the better preserved pieces. The more or less sinuous outlines of the epidermal cells can be clearly made out but no stomata are seen.

*Specimens K35/243 and K35/392*

(Pl. 4, figs. 22-24; Pl. 5, figs. 25 26)

Apart from the three well preserved specimens just described there are two others (figs. 22 and 25), both fertile but not so well preserved, which we think may be referred to the same species.

In these specimens the pinnules are longer and narrower than in the fragments just described, but some of them (figs. 22 and 23, near arrows) show a venation of the same type (cf. Pl. 3, fig. 15), though it is not so strongly marked. Most of the other characters, such as the prominent midrib, the strongly recurved pinnule margins and the form and arrangement of the sori, can also be made out.

Specimen K35/392 (fig. 25) was made into a transfer preparation to show up details (fig. 26), but even a careful examination fails to show any trace of ramental hairs.

The sori seen in the transfer are preserved badly, and only in a few places, but their circular form can be definitely made out, and the annulus is visible in several of the sporangia. The few sori where the number of sporangia can be counted contain about half a dozen sporangia each.

At one place in specimen K35/243 (marked  $\times$  in fig. 22) a group of three relatively better preserved sori was found. The sori are enlarged about thirty times in fig. 24 to show the depression in the centre characteristic of the genus *Phlebopteris*. The fragment was subsequently made into a transfer preparation but this shows nothing new or noteworthy.

In fig. 24 the sori appear to have an elliptic form and the plant was at first conjectured to be a *Matonidium* but the clear depression in the centre of the sori goes against such a view.

Genus *Cladophlebis* Brongniart

Of the sterile fern leaves there are three more or less distinct types which, for lack of data as to their exact affinities, we assign to the form-genus *Cladophlebis* although one or more of them may quite probably be the sterile leaves of *Phlebopteris*.

*Cladophlebis* (? *Phlebopteris*) sp. A

(Pl. 5, figs. 27-30)

Specimens K35/111 and K35/376 (figs. 27, 28) are counterparts of a sterile pinnate leaf fragment such as might easily have been part of a ray of *Phlebopteris*. The pinnules are slightly falcate, 6 to 8 mm. long, tapering from a base about 2 mm wide to a narrow but rounded apex. They come off at a wide angle from a rachis about 0.75 mm. thick. In each pinnule there are about 10 to 12 pairs of veins (fig. 29) which never fork more than once. There are no anastomoses.

Specimen K35/376 (figs. 28-29) was made into a transfer preparation (fig. 30) in order to bring out the details. The carbonised film, after it was cleared of mineral matter with hydrofluoric acid, was washed and then slightly macerated with potassium chlorate and nitric acid in the hope of revealing the cuticles or any spores. No traces of cell structure were visible in the thin membranous cuticle left on the slide, but adhering to it in many places, were seen numerous spores, some single, others sticking together in irregular groups. A few of these spores are shown in figs. 31 and 32.

Apart from the many spores found in more or less crushed and deformed state, it is possible to recognise two distinct kinds. One is spherical or elliptical, about  $20\mu$  to  $25\mu$  in diameter, with a moderately thick wall but no trace of a triradiate mark (fig. 31). Of this type only two isolated spores were met with.

The other kind, by far the most numerous, are generally seen in groups or masses (fig. 32) though it is impossible to assert that these masses belong to single sporangia.

The characters of this second type of spores are on the whole similar to those of the Matoniaceae, although allowance must be made for the fact that they are usually somewhat crushed. The smooth thick walls are rather characteristic. In a few cases it appears that the spores have dehisced, showing a rather wide triangular opening corresponding to the triradiate mark in *Phlebopteris*.

It is not easy to decide as to whether either of these two kinds of spores belongs to the leaf to which they are seen adhering. Indeed, the fact that there is more than one type of spore lying upon the same leaf throws both of them into suspicion as having probably been brought there by accident.

If any of these spores belong to the same species as the leaf, it is much more likely that they are of the second kind, which are much more numerous and which, as stated, recall the spores of *Phlebopteris*. This idea also accords with the general characters of the leaf, which fit in well with those of that genus. In fig. 30 we have marked with black dots the chief places where spores or spore clusters have been noticed on the transfer preparation. It is worthy of note that the great majority of these dots lie in the basal regions of the pinnules, which in the Matoniaceae are more often fertile than the distal regions of the pinnules. But it would not do to make too much of this fact, considering that in any case the spores are not in their original positions but derived from dehiscent sporangia. Taking all the facts into account we are inclined to the conclusion that the spores of the second type, shown in fig. 32, belong to the leaf on which they are found; on the whole the evidence for their having been transported seems small.

*Cladophlebis* (? *Phlebopteris*) sp. B

(Pl. 6, figs. 33 and 34)

This form (K35/358) is represented by only two pinnate fragments, both of which bear a series of well preserved falcate pinnules showing the furcate venation beautifully (fig. 34). In the natural size photograph (fig. 33) a casual view might suggest that these two rachises converge to a common petiole, and lead to the conclusion that the specimen represents parts of two diverging rays of a single *Phlebopteris*-like leaf. But a closer examination of the specimen shows that the smaller fragment overlaps the larger and lies at rather too wide an angle to belong to a neighbouring ray.

The pinnules are rather broader and longer than in *Cladophlebis* sp. A (ca. 12-15 mm. long by ca. 2.5 mm. broad at the base). The veins, too, are closer together than in that form. On each pinnule there are well over 30 pairs of veins, usually once forked. Rarely a second bifurcation can be seen near the margin. Unbranched veins have not been met with.

A detail of the venation worthy of note is that of the two arms of the fork the proximal branch is very often in direct continuation of the parent vein, while the distal branch curves forward soon after its origin and then proceeds towards the margin (cf. fig. 34a (A)). This, however, is not a

constant feature. Sometimes the veins fork at an equal angle to the parent vein, as in (B).

*Cladophlebis* (? *Phlebopteris*) sp. C

(Pl. 7, figs. 35-37)

The third sterile form is represented by two specimens (figs. 35, 37) both very fragmentary. The enlarged photographs show that the form of the pinnule is similar in the two. In both specimens the pinnules are short and almost triangular, with a slight falcate curve, and the enlarged bases of adjacent pinnules are connected together by a narrow web of lamina which forms a sort of wing to the main rachis (see fig. 35 near arrows). The latter feature, it may be incidentally mentioned, is also seen to a slight extent in the fertile specimens of *Phlebopteris hirsuta*. We need not, however, insist upon this as evidence for relating the sterile form with the *Phlebopteris*.

The venation is not well preserved. The furcate veins are somewhat distant, and in each pinnule there are usually not more than 4 or 5 veins on either side of the midrib (fig. 36 near arrows).

EVIDENCE REGARDING THE AGE OF THE STRATA

The plant remains here described are stated to have been collected from a horizon near the top of the Jurassic sequence. The evidence of their affinities tends to confirm a Jurassic age for the beds.

Both the genera *Phlebopteris* and *Cladophlebis* are known to range in geological age from the Jurassic to the Cretaceous. The genus *Cladophlebis* had a worldwide distribution in the Jurassic, while species of *Phlebopteris* are also, on the whole, more common in the Jurassic strata than in the Cretaceous.

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EXPLANATION OF PLATES

*All the figures excepting 344 are from untouched photographs.*

PLATE 1.

*Phlebopteris hirsuta* sp. nov.

1. and 2. A fertile pinna in two counterparts Nat. size.
- 3 Specimen in fig. 1 enlarged ( $\times ca. 3\frac{1}{2}$ ). M, reflexed margin of a leaflet.
4. Specimen in fig. 1 further magnified ( $\times ca. 17\frac{1}{2}$ ).

PLATE 2.

*Phlebopteris hirsuta* sp. nov (figs. 5-9, 11).

5. Transfer of part of specimen K35/124 (fig. 2) showing hairs on the rachis (R) and the pinnules (P) ( $\times ca. 12$ )
- 6 Part of a pinnule from the specimen in fig 1 magnified to show the sporangia. S, sporangia; m, midrib ( $\times ca. 46$ )
7. Mass of spores (the ?entire contents of a sporangium) with part of the sporangium wall (W) still attached ( $\times 250$ )
8. Mass of spores ( $\times 250$ ).
9. Two spores, showing the thickenings at the corners and the triradiate slit ( $\times 250$ ).
10. Spore of *Matonia pectinata* for comparison ( $\times 250$ ).
11. Mass of smaller spores ( $\times 250$ ).

PLATE 3.

*Phlebopteris indica* sp. nov

12. Part of a fertile pinna (K35/491). The photograph shows the upper side of the leaflets with their veins. The sporangia, situated on the lower side, were revealed in a transfer (see Pl. 4, fig. 18) made of this specimen ( $\times ca. 4$ )
13. Specimen in fig. 12 enlarged to show the venation ( $\times ca. 8$ ).
14. Specimen K35/537 showing the upper side of the leaflets ( $\times ca. 4$ ).
15. Specimen K35/537 magnified further ( $\times ca. 8$ ).
16. K35/532. This is a counterpart of K35/537 (fig. 14) ( $\times ca. 4$ ).
17. Cuticular preparation from a pinnule. The epidermal cells are more or less sinuous. No stomata are seen.

PLATE 4.

*Phlebopteris indica* sp. nov.

18. Transfer of specimen K35/491 (see explanation of fig. 12, Pl. 3). This is a view of the lower surface of the leaflets with a row of sori on either side of the midrib. S, sori; M, margin of the leaflet, rolled back ( $\times ca. 10\frac{1}{2}$ ).
19. Part of the transfer further enlarged to show the sori. The annulus on each sporangium is seen clearly ( $\times 43$ )
- 20 and 21. Spores. In fig. 21 one of the two spores is seen dehiscent ( $\times 250$ ).
22. A badly preserved pinna (K35/243). Near  $\times$  are seen three sori ( $\times ca. 3$ ). See fig. 24.
- 23 The three pinnules between the arrows in fig. 22 magnified further to show the venation ( $\times ca. 8$ ).
24. The three sori (near  $\times$  in fig. 22) more highly magnified. Individual sporangia can be distinguished only with difficulty due to the poor state of preservation ( $\times ca. 80$ ).

PLATE 5

*Phlebopteris indica* sp. nov. (figs. 25-26).

- 25 A badly preserved pinna (K35/892) The specimen is fertile as seen in the sori revealed on the lower surface of the leaflets in a transfer (fig. 26) made of this specimen ( $\times ca. 3$ ).
- 26. Transfer of K35/892 (fig. 25) Though poorly preserved the sori can be seen on the leaflets ( $\times ca. 3$ ).

*Cladophlebis* (? *Phlebopteris*) sp. A

(figs. 27-30)

- 27-28. Two counterparts of a pinna. Nat. size
- 29 Specimen K35/376 (shown in fig. 28) enlarged ( $\times ca. 3$ )
- 30. Transfer made from the specimen K35/376 ( $\times ca. 3$ ). The black dots indicate the approximate positions where spores have been met with (see figs. 31-32) sticking to the surface of the leaflets in the transfer preparation.
- 31. One of the two types of spores found on the transfer shown in fig. 30. This spore is of the round type ( $\times 390$ ).
- 32. A group of very much crushed spores. This is the second type of spores met with on the transfer of specimen K35/376 These spores are tetrahedral in form ( $\times 390$ )

PLATE 6.

*Cladophlebis* (? *Phlebopteris*) sp. B (figs. 33-34)

- 33. Two pinnae, probably part of the same frond. Nat. size
- 34. Specimen in fig. 33 enlarged to show the venation ( $\times ca. 3\frac{1}{2}$ ).
- 34A Sketch to show the modes of forking of the lateral veins The form most frequently seen in the specimen in fig. 34 is that shown in (A)

*Cladophlebis* (? *Phlebopteris*) sp. C (figs. 35-37)

- 35. A sterile pinna (K35/554). The arrows point to the narrow wing near the rachis, which connects the lamina of the leaflets ( $\times ca. 3$ ).
- 36. Part of the specimen K35/554 rephotographed for showing the veins (near arrows) ( $\times ca. 5$ ).
- 37. Fragment of another pinna similar to that shown in fig. 35 ( $\times 5$ ).

## STUDIES IN FLORAL ANATOMY

### III. *On the Origin and Orientation of Placental Strands.*

BY

V. PURI, D.Sc.,

MEERUT COLLEGE, MEERUT

(With ten figures in the text)

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#### ABSTRACT

The paper deals with the study of origin and orientation of placental strands in a number of families particularly the *Rhoadales*. It is concluded that the theory of carpel specialization, as originally suggested by Eames and Wilson for *Cruciferae* and subsequently applied to *Papaveraceae*, *Moringaceae*, etc., rests upon incorrect interpretation of the origin and orientation of these bundles. For instance, what have so far been regarded as marginal bundles of carpels are now best explained as stelar bundles which ultimately differentiate into placental strands. In the same way the inverse orientation, which so far was interpreted as evidence of solidification of carpels in *Cruciferae*, *Moringaceae*, etc., is here believed to be merely an ancestral mark left behind to betray, as it were, the fact that parietal placentation in these families has evolved from axile placentation. Thus the entire anatomical support, which the theory of carpel specialization received through the courtesy of Eames and Wilson, has to be completely withdrawn and we have once more to revert to the classical view as to the nature and number of carpels in the rhoeadalean families.

Diversities in interpreting the origin and orientation of placental strands have been the cause of great confusion in the determination of nature and number of carpels in the rhoeadalean families in general and *Cruciferae* in particular. The inverse orientation of these bundles was first noticed by Gerber\* in 1900 in the *Cruciferae*, who interpreted it as an evidence of there being six carpels in the crucifer gynaecium—four on the periphery and two inverted ones forming the replum in the centre. Hanning (1901\*) adduced further evidence in support of this interpretation by recording inverse orientation in a number of other species and by studying the origin of placental strands in them. More recent publications which deserve mention in this connection are those of Eames and Wilson (1928, 1930), Dickson (1934) and Puri (1941, 1942). All these authors have based their interpretations on the mode of origin and inverse orientation of placental strands.

My study of the problem in a number of families, particularly *Rhœadales*, induces me to think that the whole support, which the theory of carpel specialization, as originally suggested by Eames and Wilson (1928) for *Cruciferae* and subsequently applied to *Papaveraceae*, *Moringaceae*, etc., receives from vascular anatomy, rests upon incorrect interpretation of: (1) the origin and behaviour of marginal bundles of carpels and (2) the inverse orientation of vascular tissue in placental strands. It will, therefore, be worthwhile to focus some attention on these two aspects of the question even though it may involve some repetition.

*The Origin and Behaviour of Marginal Bundles.*—Ordinarily the origin of a trace is determined at the point of its departure from the stele. In cases like *Conringia orientalis* (Eames and Wilson, 1930) where the receptacular bundles continue beyond the passing out of the last traces for the carpels such a departure is easily noticeable and consequently it can be definitely determined when exactly the stelar bundles become the marginal traces for the carpels. In majority of cases, however, no receptacular bundles proceed beyond the origin of marginal traces. In fact there are left just as many bundles in the stele as the number of marginal traces (or their fusion products) required. For all practical purposes they are identical with marginal bundles (cf. Eames 1931, p. 174); but interpreting them as such, in the past, has proved disastrous to the understanding of crucifer gynaecium in particular and other rhœadalean gynaecia in general. A few illustrations will make the point clear.

In *Passiflora*<sup>1</sup> the dorsal bundles for the three (sometimes four) carpels are the first to depart (fig. 1, C, bundles D<sub>1</sub>, D<sub>2</sub>, D<sub>3</sub>). They are immediately followed by three median marginal strands (fig. 1, D, bundles M<sub>1</sub>, M<sub>2</sub>, M<sub>3</sub>) which are fusion products of the median marginal veins, a fact substantiated by their frequent bifurcation towards the tip. This leaves the vascular cylinder with only six bundles which are generally very small and fuse in pairs on the inner side of median marginal strands (fig. 1, E, G, bundles a, b; c, d; e, f). While doing so they rotate through 180 degrees and become inversely oriented. Following the interpretation of corresponding bundles in other families, particularly *Cruciferae* and *Moringaceae*, I was, in the beginning, led to regard them as marginal bundles. But now it is realized that such an interpretation would introduce serious complexities which can otherwise be conveniently avoided. It is more convincing to regard them as

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<sup>1</sup>This general account is based on the study of about half a dozen species of *Passiflora*, whose detailed account is under preparation and will be published separately

stellar bundles which fuse in pairs to close the last gaps. Their fusion products give rise to placental strands with inverse orientation.

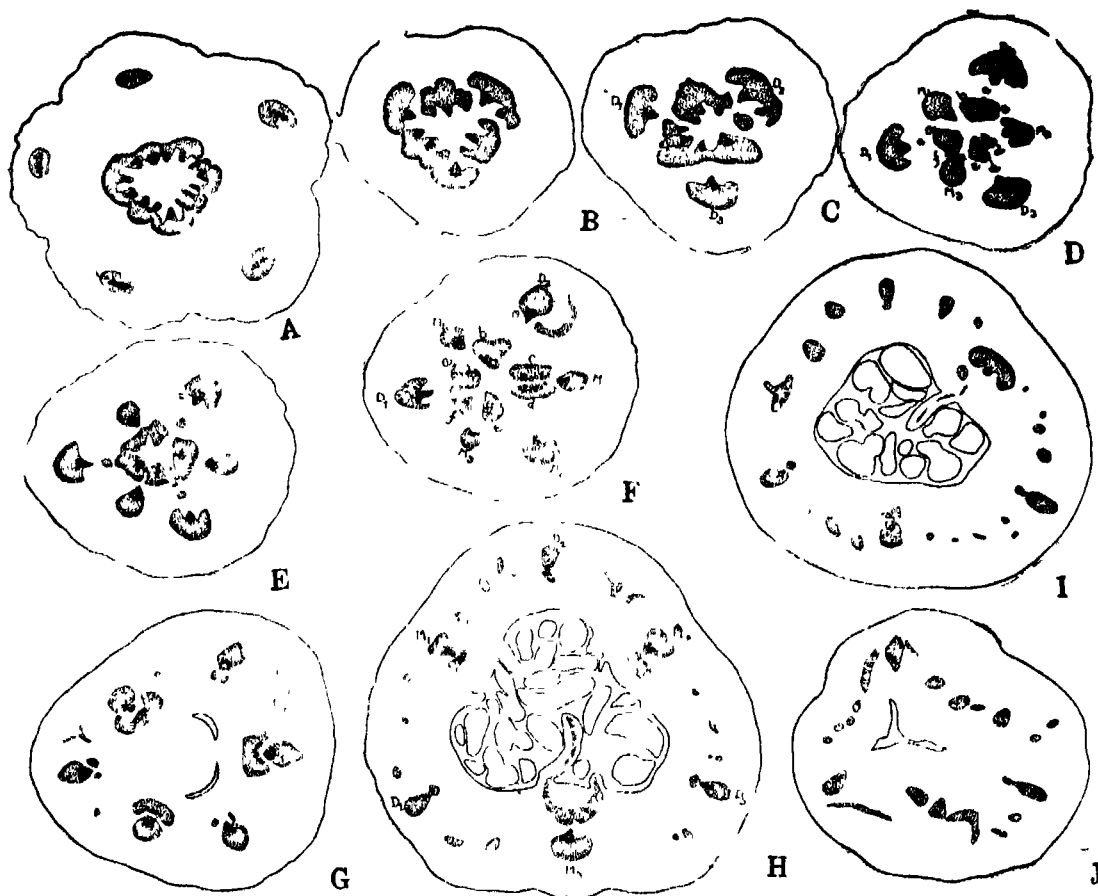


Fig. 1

Fig. 1, A-J ( $\times 24$ ) *Passiflora holosericea*. A—T.s. androgynophore with five stamens about to separate off. B-J—T.s. gynaecium from base upward. For explanation see text.

The condition in *Moringaceæ*, *Cruciferae*, *Cupparidaceæ*, *Papaveraceæ*, etc., is almost the same. But in all these families bundles corresponding to *a, b, c, d, e, f*; etc., have been erroneously interpreted as marginal bundles which swing inward and fuse in pairs to form the inversely oriented placental strands in exactly the same way as they do in closed carpels. Their behaviour and inverse orientation (Eames and Wilson, 1928, 1930; Dickson, 1934; Puri, 1942) and sometimes only the latter (Puri, 1941) has been regarded as evidence of solidification of closed carpels.

In the case of *Moringaceæ*, for instance, I interpreted these stelar bundles as marginal veins which swing inward and fuse in pairs on the inner

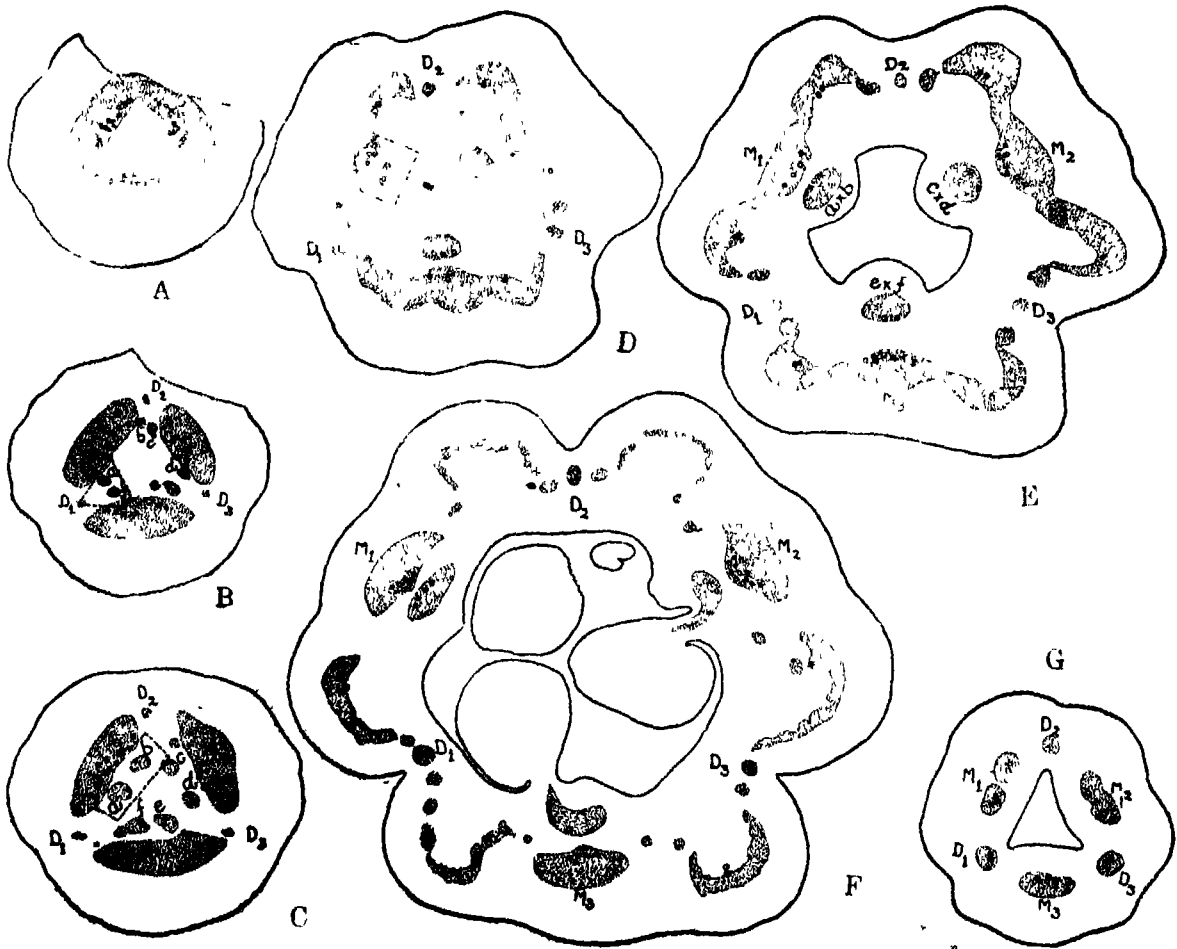


Fig 2

Fig. 2, A-G. ( $\times 42$ ) *Moringa oleifera*. T.s. gynaecium from base upward. A—Shows the complete vascular cylinder in the base. B-C—stelar bundles a, b, c, d; & e, f, are passing in leaving behind the dorsals, D<sub>1</sub>, D<sub>2</sub>, D<sub>3</sub>. D-E—Inverted placental strands have been formed on the inner side of median marginal strands, M<sub>1</sub>, M<sub>2</sub>, M<sub>3</sub>. F—Ovular traces are given out from the placental strands. G—Placental strands have either disappeared completely or their last traces have fused with the median marginals. Their splitting into two each in the upper region indicates that they are formed by the fusion of two marginals.

side of what there were regarded as the dorsal bundles of the carpels (Puri, 1942). Such an interpretation was imposed on these bundles for four reasons

whose unsound nature can now be realized in the light of my work on *Passifloraceæ* (1) The real dorsal bundles of carpels are not clearly distinguishable in this region. As stated elsewhere (Puri, 1942, postscript), they have been observed only with difficulty. (2) While generally it is traces which leave the stele, in *Moringa* the stelar bundles pass inward leaving the rest of the stele as appendicular (fig. 2, B-C). (3) The behaviour of these last

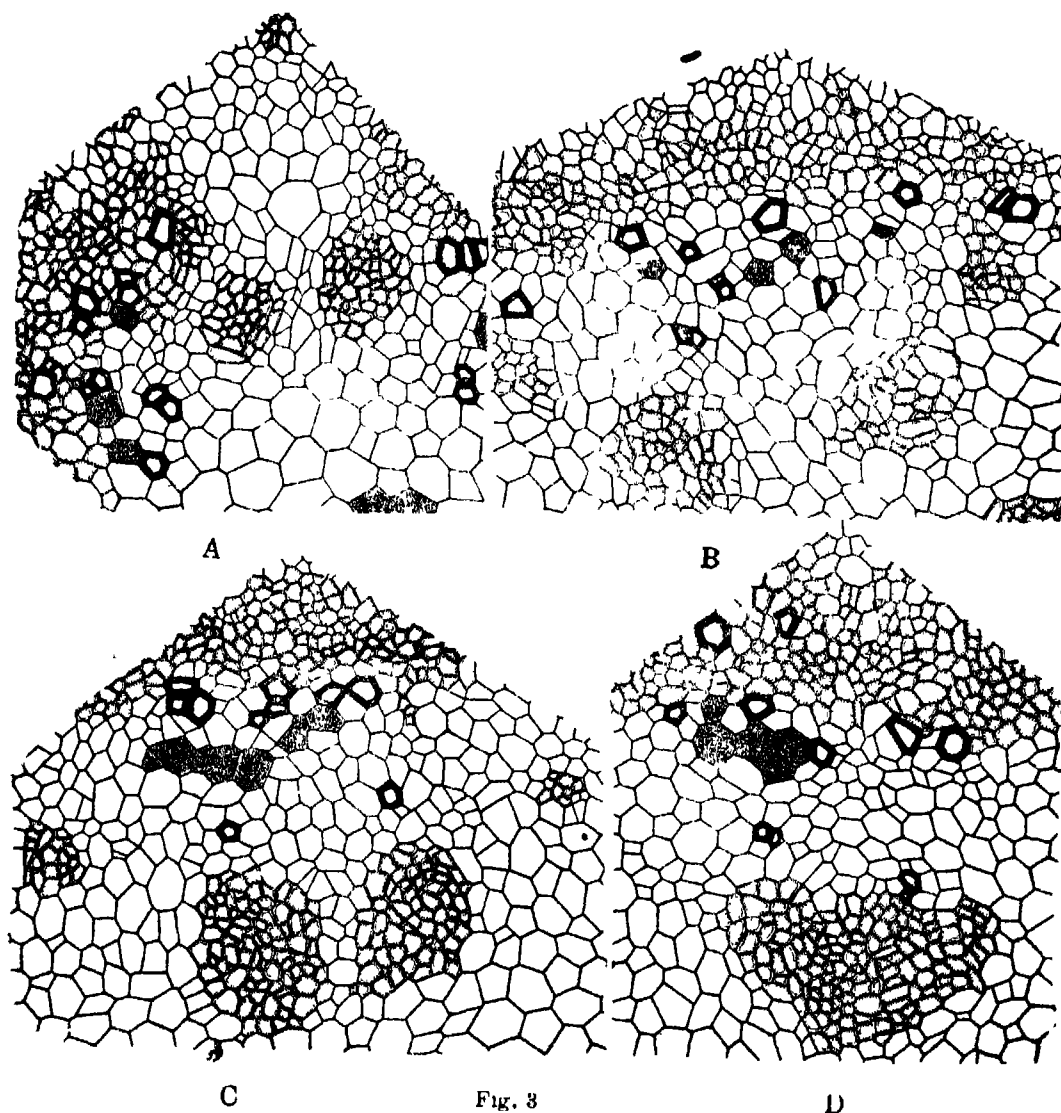


Fig. 3

Fig. 3, A-D. ( $\times 425$ ) *Moringa oleifera*. A, B & D—magnified views of areas marked in fig. 2, B, C & D respectively. C—The last stelar bundles, a, b, have come to lie close together on the inner side of the median marginal strand.

stelar bundles, *a, b; c, d; e, f*, their swinging inward and fusing in pairs on the inner side of other bundles is suggestive of their interpretation as marginal bundles (fig. 2, *C-D* and 3, *A-D*). (4) Last but not the least important is the inverse orientation of their fusion products.

Now the *Moringa* gynaecium can be more conveniently explained as consisting of three valve carpels which fuse together by their margins (Classical view). The bundles  $D_1, D_2, D_3$ , (Corresponding to bundles *X, Y, Z* in Puri, 1942, fig. 4, *1*) are to be regarded as dorsal bundles of the three carpels;  $M_1, M_2$  &  $M_3$ , as median marginal strands formed by the fusion of median marginal veins; and *a, b; c, d; e, f*, as the last stelar bundles which, during their inward course become inversely oriented and after fusing in pairs give rise to three placental strands on the inner side of  $M_1, M_2$  and  $M_3$  (figs. 2, *B-D* and 3, *A-D*). In some cases these stelar bundles are followed by very small branches of phloem tissue which may disappear even before the formation of placental strands (fig. 3, *B-C*).

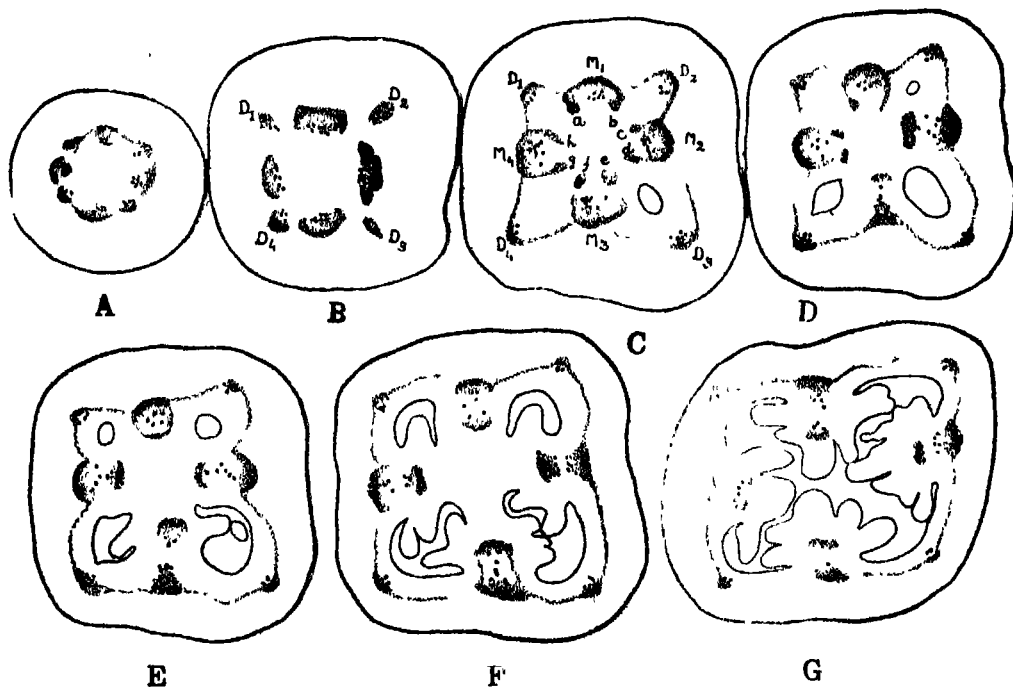


Fig. 4

Fig. 4, A-G. ( $\times 42$ ) *Capparis horrida*. A—Vascular ring in the base of the gynaecium consisting of 4 small and 4 large bundles. B—The four small ones passing out as carpellary dorsals,  $D_1, D_2, D_3, D_4$ . C—Stelar bundles, *a, b; c, d; e, f; g, h*, are being detached from the median marginal stands,  $M_1, M_2, M_3, M_4$ . D-G—They are fusing into inverted bundles which become the placental strands.



In Cruciferae also, as pointed out earlier (Puri, 1941), bundles corresponding to *a,b; c,d; etc.*, have been misunderstood in the same way. Their correct interpretation now renders special support to the classical view of there being only two carpels in the crucifer gynaecium. After the passing out of the so-called replum strands, which should henceforth be regarded as median marginal strands — fusion products of median marginal veins —, the remaining stelar bundles which are generally four corresponding to *a,b* and *c,d*, proceed inward and after anastomosing in a number of ways (cf. Puri, 1941) differentiate into two inverted bundles in the antero-posterior plane which immediately become the placental strands.

I have cut serial microtome sections of a number of *Capparidaceae* (*Capparis horrida*,<sup>2</sup> *C. aphylla*, *C. sepæria*, *Gynandropsis pentaphylla* *Crataeva religiosa*), and found that in all of them (*Crataeva* provides some exceptions) the placental strands arise in exactly the same way as in *Passifloraceae*. The only point which deserves special attention here is that in all the *Capparis* species mentioned above the last stelar bundles, *a,b; c,d; e,f*, etc., swing in and fuse in pairs so close to the median marginal strands that they make the latter appear as concentric and as giving out placental strands as branches (figs. 4, *C-E* and 5, *A-D*).

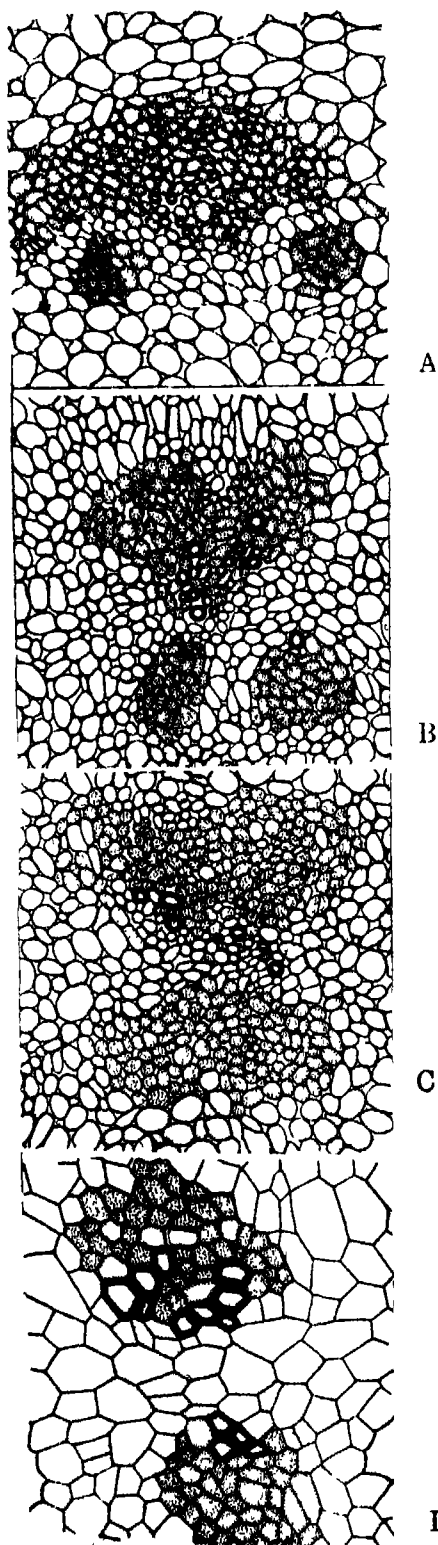
In *Gynandropsis pentaphylla* the last stelar traces proceed inward and fuse to form a central plexus which immediately breaks up into two parts in the antero-posterior plane. Each part has its xylem directed outwards and develops into an inverted placental strand (fig. 6, *A-K*).

*Crataeva religiosa* presents some interesting variations which will be dealt with in detail in a separate paper. The gynaecium is usually bicarpellary syncarpous with two large parietal placentae. In some cases the ovary is bilocular at both base and apex where the placentation is axile but unilocular in the middle where the placentation is parietal (fig. 7, *F-L*). The natural inference from such an observation is that the unilocular condition has been derived from bilocular.

Additional support for such an inference is obtainable from the vascular supply of the ovary which is derived from two different rings of vascular tissue. The outer ring is a continuation of the main stele and is used up in giving rise to dorsals and median marginal strands. The inner ring, on the other hand, arises *de novo* in the upper region of the receptacle and supplies only

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<sup>2</sup>I am thankful to Dr. P. Maheshwari for placing some of his prepared slides of this species at my disposal.



the placental strands. It has no connection, whatsoever, with the outer ring at the place of its origin (fig 7, A-B). To begin with a few deeply staining cells make their appearance in the pith of the receptacle before the passing out of the dorsal traces for the carpels. A little higher up a few xylem elements also become evident (fig 8, A). Their number soon increases and then some vascular bundles differentiate which arrange themselves in a ring round a parenchymatous core (fig. 8, B-D). Curiously enough all these bundles are inversely oriented with reference to those of the outer ring. At the level of the origin of loculi a portion of the inner ring gets detached on each side in the antero-posterior plane (fig. 7, F). This migrates out towards the corresponding median marginal strand and becomes the inverted placental bundle (fig. 7, G-H). The remaining portion of the stele separates into distinct bundles which become traces for the ovules arising from the middle region of the partition (fig. 7, G).

In some cases although the ovary is bilocular in the lower region there are no ovules in the axial

Fig. 5

Fig. 5, A-C. ( $\times 425$ ) *Capparis horrida*. A—Median marginal strand getting rid of the last stelar bundles *a, b*. B—The latter approaching one another on the inner side of the former. C—They have fused into an inverted bundle which becomes the placental strand. D ( $\times 725$ ) *Capparis aphylla*. Inverted placental strand on the inner side of median marginal strand.

position. Here no bundles may be left in the inner ring after the migration of portions destined to produce placental strands.

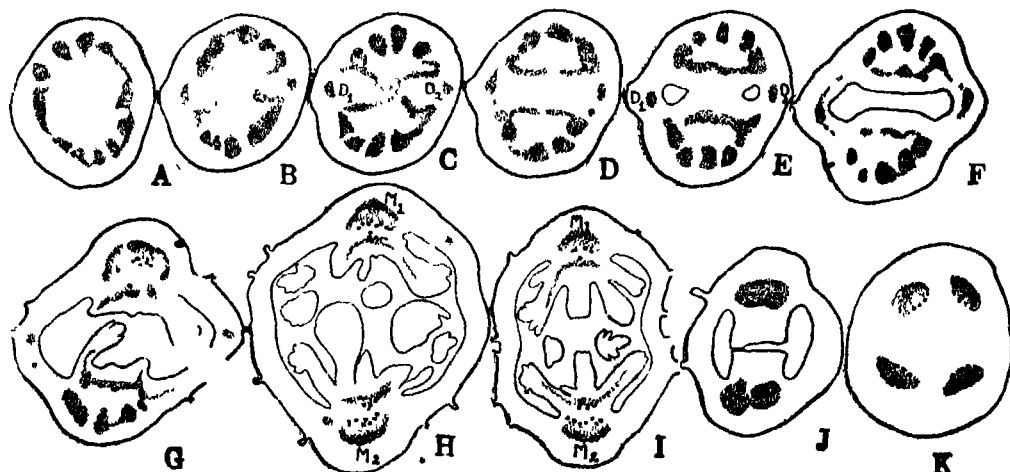


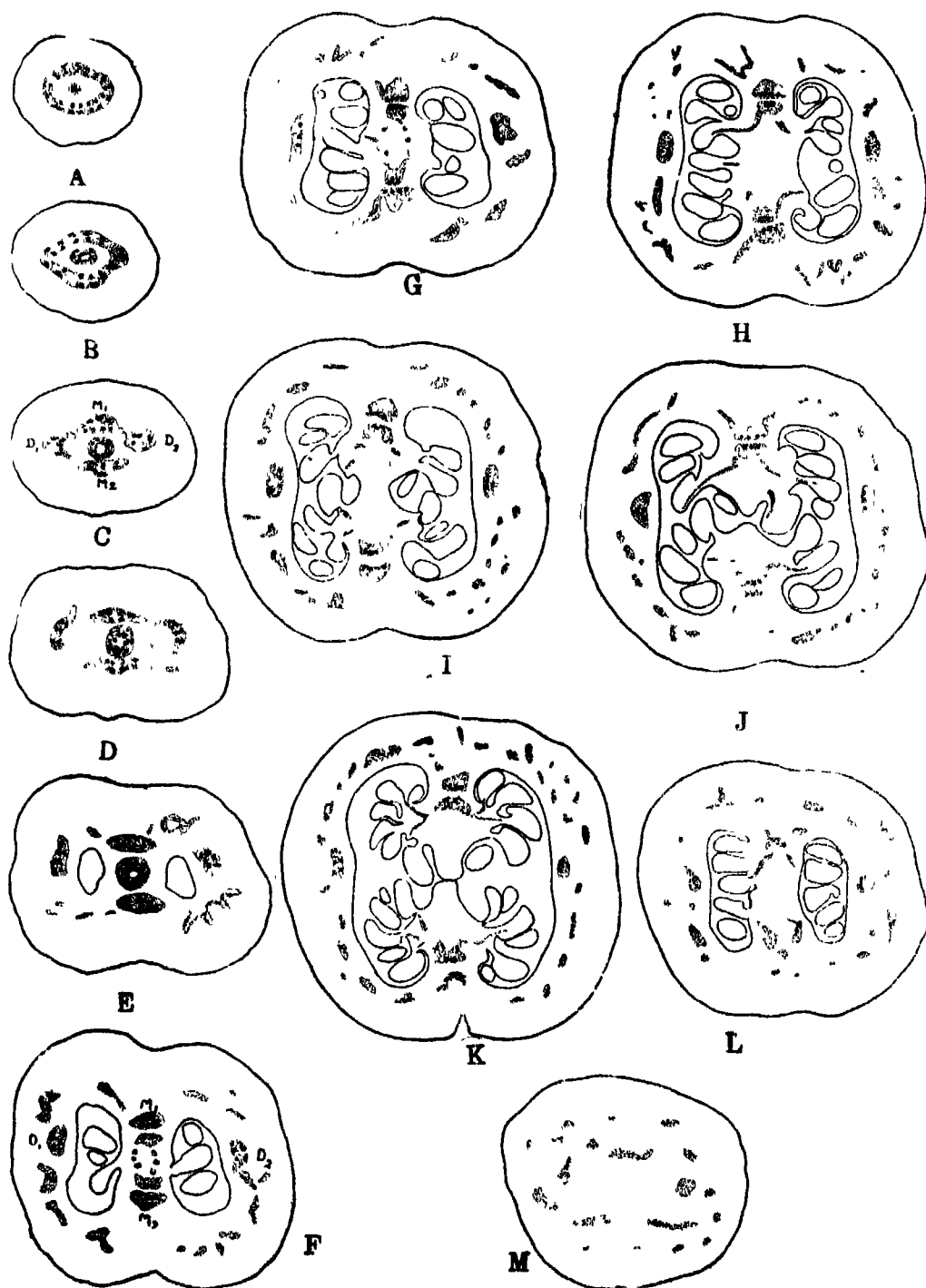
Fig. 6

Fig. 6, A-K ( $\times 22$ ) *Gynandropsis pentaphylla*. The last stelar bundles which are not quite distinct here fuse into a central plexus from which the placental strands arise. The dorsals have disappeared in the upper region and the median marginal strands have splitted up into two each.

These observations indicate the way in which *Cratæva* gynaeceum may have been obtained. It appears thus quite likely that it has evolved from a multicarpellary ancestor with axile placentation having a central ring of inverted placental strands (cf. fig. 10). Although the axial placentae have now been replaced by parietal ones this central ring with its inverse orientation has been retained in *Cratæva religiosa* to give rise to inverted placental strands for two parietal placentae.

In the light of this interpretation the *de novo* origin of the inner ring of vascular tissue is not difficult to visualize. In cases where the axile placentation has become sufficiently "deep-seated" it is quite likely that the placental strands lost all connections with the outer ring from which all other carpellary traces are given out, and arose independently *in situ*. Such a condition may actually be occurring in a number of cases although I have not had the chance of coming across with any so far.

Study of *Cucurbitaceæ*, which is in progress in this laboratory, reveals that in a number of cucurbits also the placental strands arise *de novo* and that they are inverted from the beginning.



**Fig. 7**

Fig. 7, A-M ( $\times 22$ ) *Cratzea religiosa*. T.s. of gynaecium from base upward. For explanation see text.

In *Darbya* also Smith and Smith (1942) report the derivation of vascular supply of the ovary from an inner inverted ring of vascular tissue which

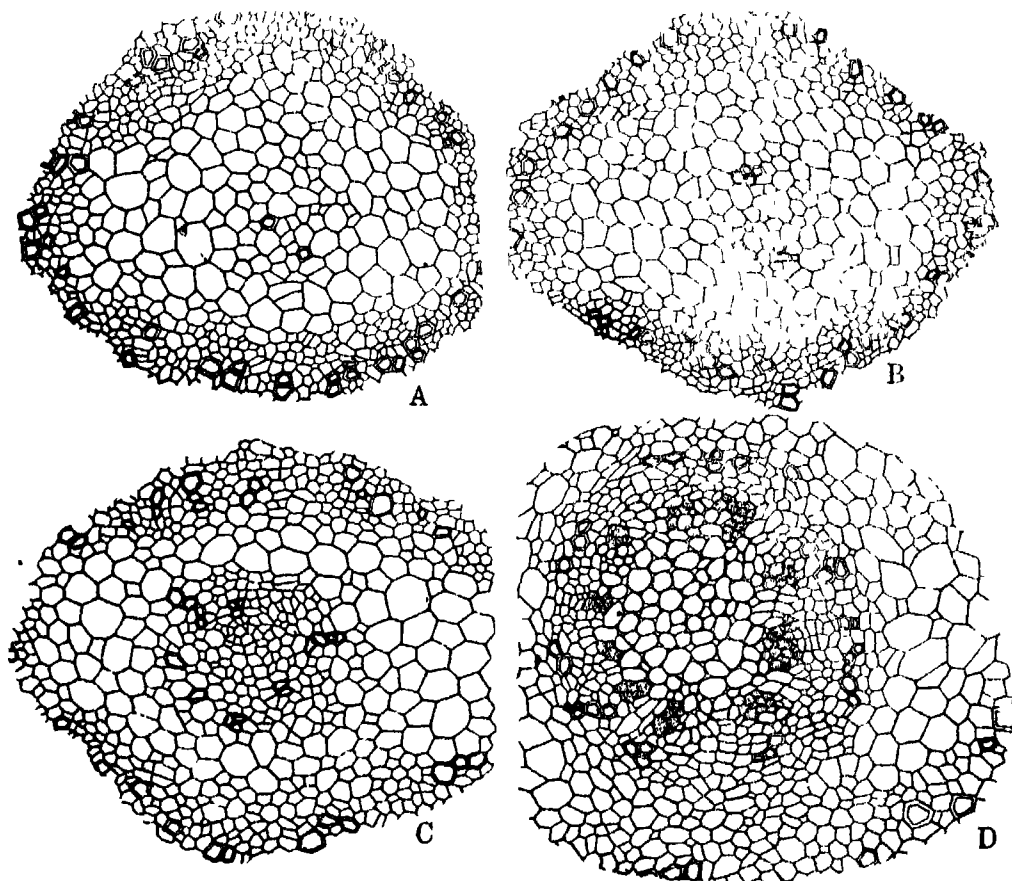


Fig 8

Fig. 8, A-D ( $\times 190$ ) *Crataeva religiosa*. Showing differentiation of the inner ring of inverted bundles. Vascular elements towards the periphery belong to the outer ring.

appears to arise *de novo* but which is interpreted by them as being formed by recurrent bundles of the outer ring.

Instances of *de novo* origin of vascular bundles other than the placental strands are many but they have evidently little bearing on the subject under review.

In some of the *Papaveraceae* also the last stelar bundles which are usually without any xylem elements, swing in so close to the median marginal

strands that their individuality has probably been missed by Arber (1938). She interprets the outer bundles (labelled by her as marginal strands but here regarded as median marginal strands) as becoming concentric to cut off inverted bundles for the placental region.

*The Inverse Orientation of Placental Strands.*—In the case of closed carpels with typical axile placentation where the margins of a carpel fuse together the placental strands form an inner ring and lie inversely oriented on the radii of the dorsals. The inversion of these strands can be easily visualized on the presumption that the marginal bundles, which form the placental strands, follow the course of the carpellary margins.

In the case of typical parietal placentation, on the other hand, the open carpels fuse end to end and all the bundles, the dorsals, the median marginals, and the placental strands, which are normally oriented, lie in one peripheral ring.

Both these cases are simple and need no attention. What is to be considered here is the condition which is somewhat intermediate between these two extremes. Arranged though they are on alternate radii, the dorsals and the placental strands lie in two different rings and the latter are inversely oriented. Such a condition has been observed to be very common particularly in the rhoeadalean families and doubtlessly it will be found to be of more general occurrence than hitherto known as more investigations on the subject come forward.

In *Cruciferae* such a condition has been shown to be almost universal (Eames and Wilson, 1928, 1930; Arber, 1931a, 1931b; Puri, 1941). It is also equally common in *Moringaceae* (Puri, 1942). I have observed inverted placental strands in a number of *Capparidaceae* also. In *Crataeva religiosa*, as pointed out earlier, the whole ring of vascular tissue which supplies these strands is composed of inversely oriented bundles from the beginning. In *Papaveraceae* also they are inversely oriented in a number of species (Dickson, 1934; Arber, 1938).

I have examined serial microtome sections of a number of *Reseda*<sup>3</sup> species and found that the placental strands are normally oriented in *Reseda alba*, *R. glauca*, *R. lutea* and *R. odorata*. Although the placentae are quite

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<sup>3</sup> I am thankful to Dr. P. Maheshwari for the alcohol-preserved material of *Reseda alba*, *R. glauca*, and *R. lutea* and to the late Sir A. W. Hill for freshly pressed material of *R. luteola*.

massive in almost all of them there are no median marginal strands outside the placental strands. *Reseda luteola*, however, is slightly different. Here the marginal bundles, which remain quite distinct, break up into two parallel series of vascular bundles which are only half inverted (fig. 9, D-E). In some cases some of the innermost branches may become completely inverted. Higher up, where the carpels separate apart and the carpellary margins fold more and more inward, almost all of these branches become inversely oriented with reference to the outer ones (fig. 9, F-G).

In a number of *Passifloraceæ* also inverted placental strands have been observed lying on the inner side of median marginal strands. They are much extended laterally and may give out several ovular traces simultaneously. Some of the cucurbits also show the same condition.

This is by no means an exhaustive list of such cases known; a careful search through the literature on the subject will reveal many more instances of this type. But the fact that inverted placental strands do occur in parietal placentae also is more than established.

The inversion of these strands has been variously explained. Eames and Wilson's views (1928, 1930) on the subject are too well known to be restated here in detail (see Puri, 1941). On the basis of the study of vascular scheme they have suggested that there are four carpels in the crucifer gynaecium—two closed solid and two open valve. In the closed carpels the ventral sutures, and consequently the placental strands formed by the fusion of marginals, lie on the inner side of the dorsal sutures. Thus the inversion of the placental strands is effected in the same way as in the typical case of axile placentation.

With certain modifications I had supported Eames and Wilson's interpretation for *Cruciferae* (Puri, 1941) and had reached the same conclusion myself with respect to *Moringaceæ* (Puri, 1942). But now in view of my my more recent work on the *Passifloraceæ* I am obliged to withdraw support to this interpretation.

Arber (1938) has suggested a very easy, though not so convincing, mechanism for the inversion of the bundles in the placental region. She writes (Arber, 1938, p. 661):

"It must be remembered that each placenta is immediately internal to one of the strands which are here interpreted as fused marginals. Exactly how such a strand can supply bundles to the placenta which is on its own radius, is a special case of the general problem of how a collateral bundle can give off a branch on its xylem side. In *Papaver Rhoeas*, as

we have seen, this problem is solved by the bundle becoming concentric, when a portion of it is detached on the side towards the placenta, it thus naturally has its xylem turned towards the parent strand and its phloem away, in other words it is inverted."

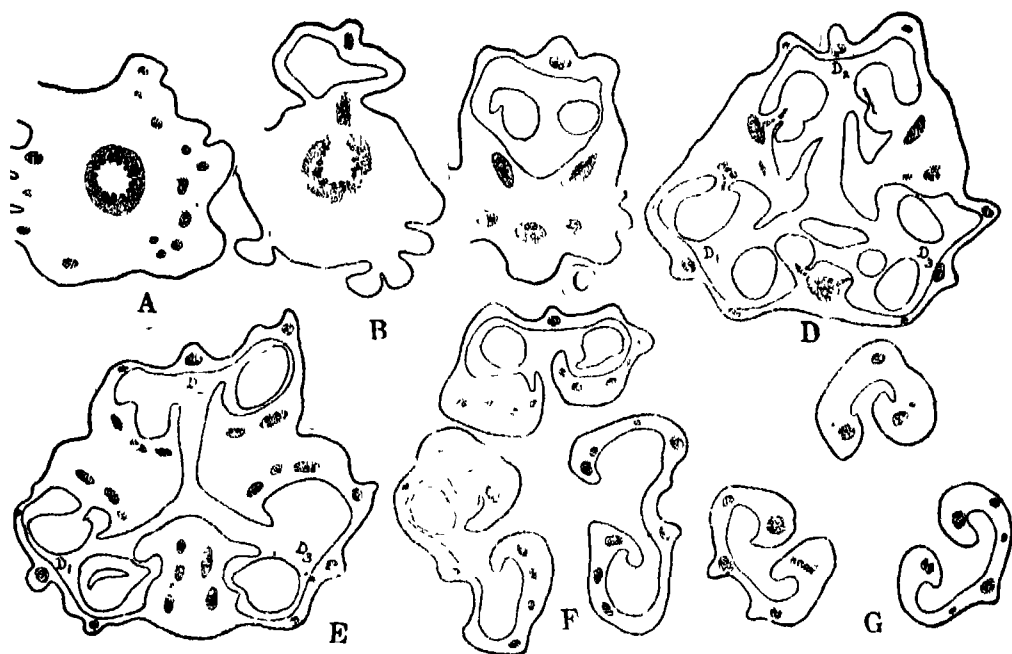


Fig. 9

Fig. 9, A-G ( $\times 42$ ) *Rhus luteola*. A—Vascular cylinder entering the base of the ovary. B—Dorsal bundle for one carpel cut twice. C-F—The alternating three bundles break up into two series of marginal bundles each. F-G—Carpels separate apart and the inner branches become completely inverted.

In the first place such a mechanical interpretation does not appear to be quite plausible to a student of anatomy who knows how vascular bundles differentiate and understands the limitations of such terms as "branching," "splitting," "running", "passing", etc., when used in connection with vascular bundles. In fact vascular bundles are always laid down in the form of procambial strands which differentiate into xylem and phloem in accordance with set laws which vary with the organs, roots, stems, etc. It is consequently not possible to explain the inversion of these bundles without presuming that the carpellary margins themselves are inverted, as it happens in the case of axile placentation.

Moreover, such an explanation of the inversion cannot be applied to a large number of cases mentioned above, e. g., *Cruciferae*, *Passifloraceae*, etc.,



where the inverted bundles have no direct connection with the outer bundles.

Further, I think Mrs. Arber is not dealing with genuinely concentric bundles in *Papaver Rhoeas*. What appears to me to be the correct position is that the last stelar bundles corresponding to *a,b; c,d; e,f*; etc., swing in so close to the median marginal strands that they appear as part and parcel of the latter; and since they generally consist of phloem only, there being no xylem elements, they evidently make the median marginal strands look concentric. Consequently the bundles are not branching as believed to be the case by Mrs. Arber but simply separating off the last stelar bundles which happened to come so close to them.

Spratt (1932) dismisses the whole problem of inversion of placental strands by suggesting that "it is associated with the fact that they are placental bundles."

Eggers (1935)<sup>4</sup> has adopted altogether a different line of attack on this problem. He discards all phylogenetic explanations of inversion of placental strands mainly on two grounds. In the first place, he argues, the folding in of the carpellary margins which is presumed in all such explanations, has never been observed during development. Secondly even if we take for granted that a phylogenetic explanation accounts for cases of axile placentation we would have to employ fundamentally different interpretation for the inversion of placental strands in the rhoeadalean families. He, therefore, believes that the inverse orientation of placental bundle is closely related to the morphological nature of placentae and their late development. But this relation, he adds, is still obscure in some respects.

I do not see much conviction in his first argument, for it is not always possible to have clear glimpses of past history of plant organs in their ontogeny. His second objection is merely a false apprehension as will be clear from the following account.

One of the simplest ways in which the inversion of parietal placental strands may be effected is as follows<sup>5</sup>: The carpellary margins of the ordinary valve carpels fold inward and then spread out a little so as to lie almost parallel and internal to the main body of the carpels. If in this condition the carpels fuse together by their sides leading to the fusion of marginal bundles the resulting placental strands will be inverted. That

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<sup>4</sup> I am grateful to Professor B. Sahni, F.R.S., for helping me with the translation of a passage from this paper.

<sup>5</sup> I owe the impetus for it to certain suggestive remarks made by Dr. A. C. Joshi of Benares during a friendly talk early in May, 1943.

such is a possibility is indicated to a certain extent in *Rosa luteola*. As stated above the marginal bundles in this species remain quite distinct (do not fuse into placental strands) and branch into two series of half-inverted bundles with their xylems directed outwards and phloems inwards (fig. 9, E). Some of the innermost branches towards the extreme tips of the carpellary margins may become completely inverted. If this condition becomes permanent and if the bundles fuse together the resulting placental strands will be automatically inverted.

I cannot say how far, if at all, this explanation actually solves the problem of inversion of parietal placental strands. It is, however, evident that it cannot cover cases as met with in *Crataeva religiosa* where there exists an internal ring of inverted vascular bundles to give rise to inverted placental strands.

There is yet another interpretation which can satisfactorily account for such cases as well. It has already been suggested that the unilocular condition in *Crataeva religiosa* may have evolved from multilocular one. The same conclusion can be reasonably applied to the remaining *Cappariaceæ*, and *Cruciferae*, *Moringaceæ*, *Passifloraceæ*, etc. This being so the parietal placentation in all these cases must have been obtained from axile placentation. The mechanism by which such a change may have been brought about seems to be quite simple and is illustrated in fig. 10. Each axile placenta, as also its placental strand which is naturally inverted, splitted up into its two component halves which then fused with contiguous halves of the other placentae to form an equal number of parietal placentae.

Although there is left no indication of axile placentation in many of these forms (unless the presence of false septum, so common in the *Rhoïdales*, is interpreted as one such) the inversion of the placental strands has been retained as an ancestral mark to baffle, as it were, the students of floral anatomy.

That such is actually the correct explanation of inversion of parietal placental strands is more clearly seen in *Crataeva religiosa*. Here, as has been pointed out earlier, the internal ring which supplies placental strands itself becomes inverted from the beginning. Since giving out these strands is the only function of this ring, it seems quite probable that it arose there by downward prolongation of the axile placental strands in the ancestral forms. This appears to me to be the only correct explanation of the *de novo* origin and inversion of the inner ring.

Woodson and Moore` (1938) have suggested that parietal placentation in certain *Apocynaceae* has also been obtained from axile placentation in much

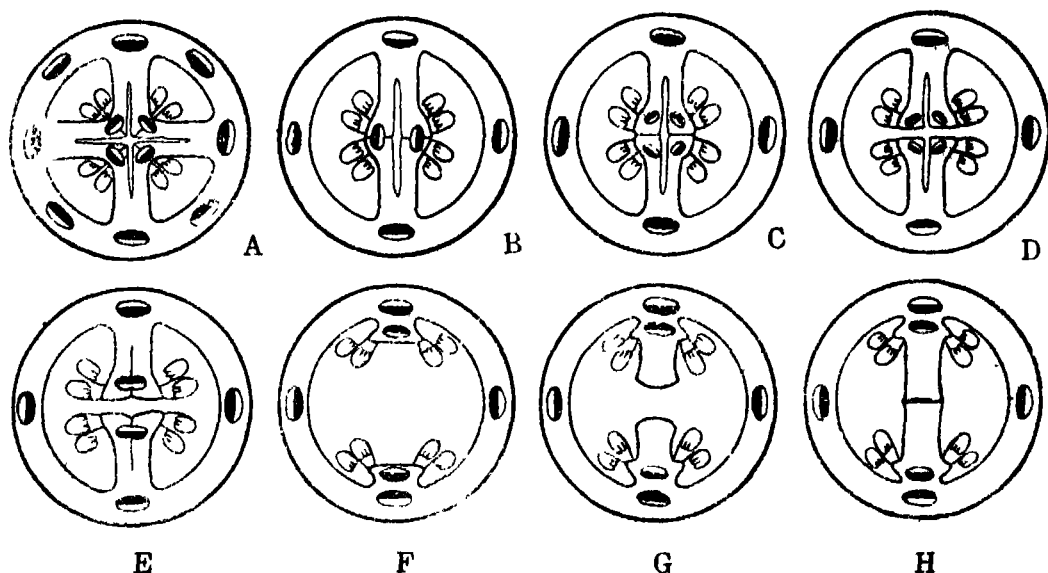


Fig. 10

Fig. 10, A-H—Diagrams showing the author's opinion of the method of development of the crucifer ovary. A—Multicapellary ancestor with typical axile placentation. Inverted placental strands lie on the radii of the dorsals and form an inner ring (cf. *Crataeva religiosa*) B—Number of carpels reduced to two (ovules not reduced). C-E—Each of the axile placentae splits up into its components which fuse with adjacent halves of the other carpels to form an equal number of parietal placentae with inverted bundles. F—Margins shorten and the placentae are brought very near to the median marginal strands. G-H—Outgrowths from the placentae fuse in the centre and form the false septum.

the same way. But they do not draw any attention to the orientation of vascular tissue in the placental strands nor do their figures throw any light on this aspect of the subject.

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3. (x60.3 1/2)



1. (x1)



2. (x1)



4. (x Ca. 17 1/2)



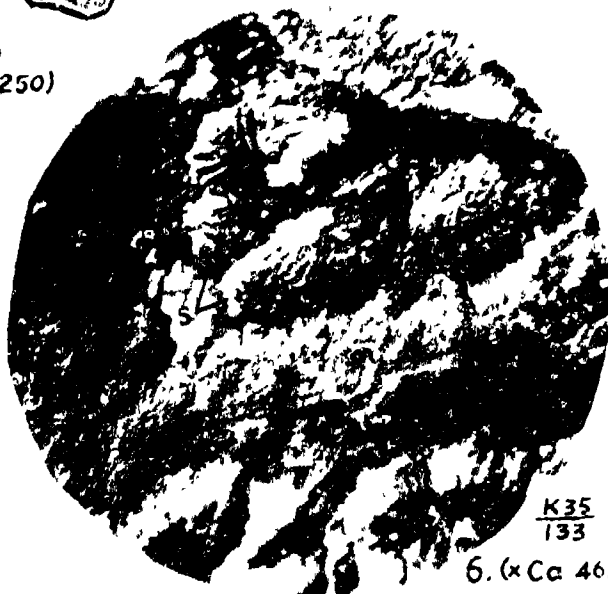
5. (x Ca. 12)



7  
(x250)



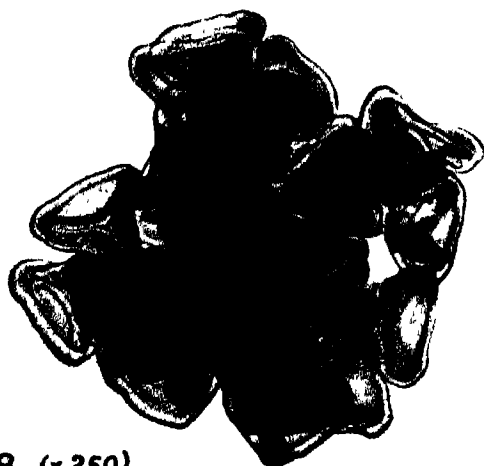
10  
(x250)



6. (x Ca 46)



9. (x 250)



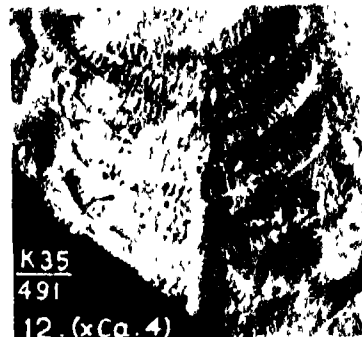
8. (x 250)

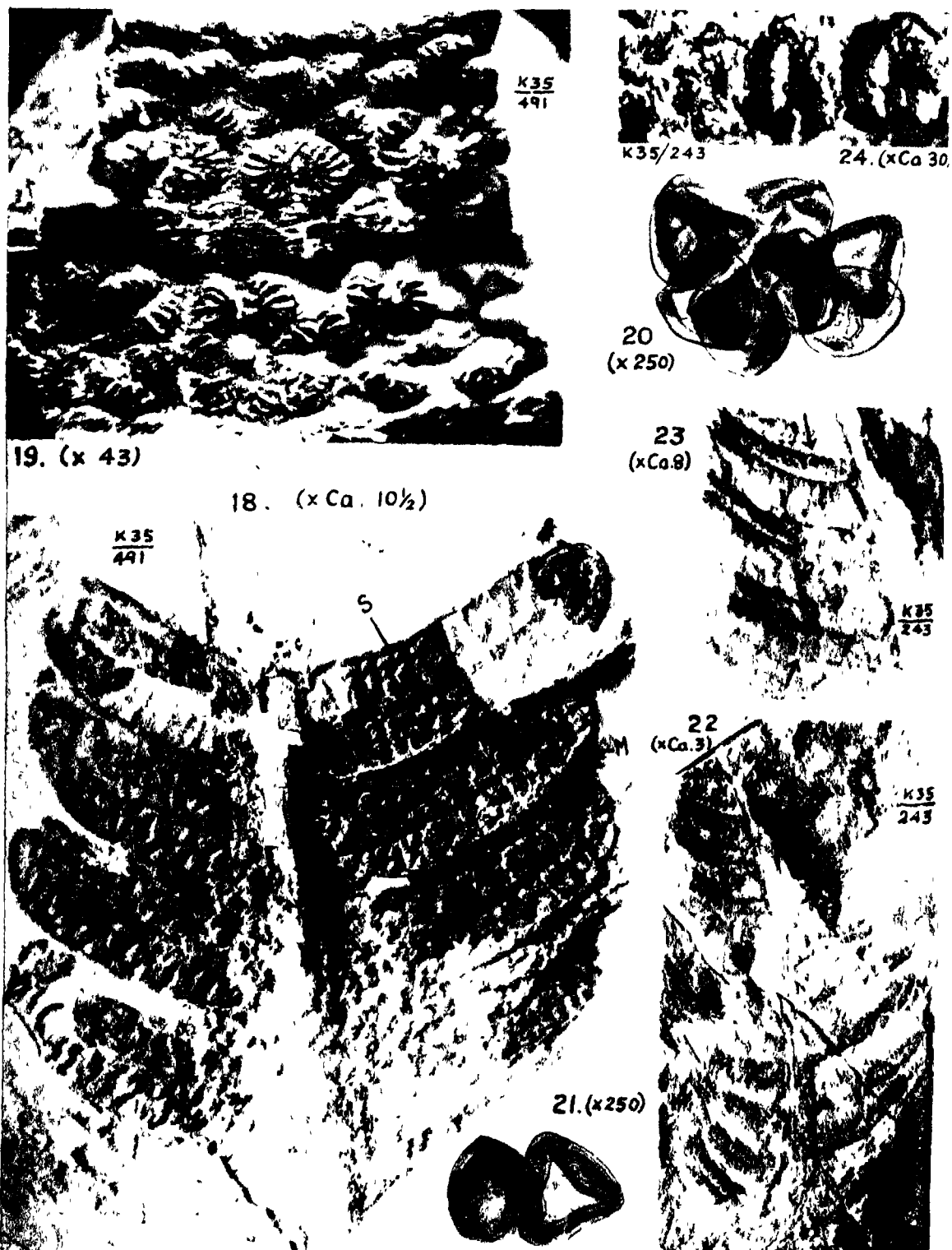


11. (x 250)

R. V. S. Photos.

5-9, 11 : *Phlebopteris hirsuta* sp. nov.  
10 : *Matonia pectinata*







29. (x Ca. 3)



31. (x 390)



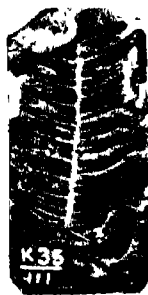
32. (x 390)



30. (x Ca. 3)



25. (x Ca. 3)



27. x1



28. x1



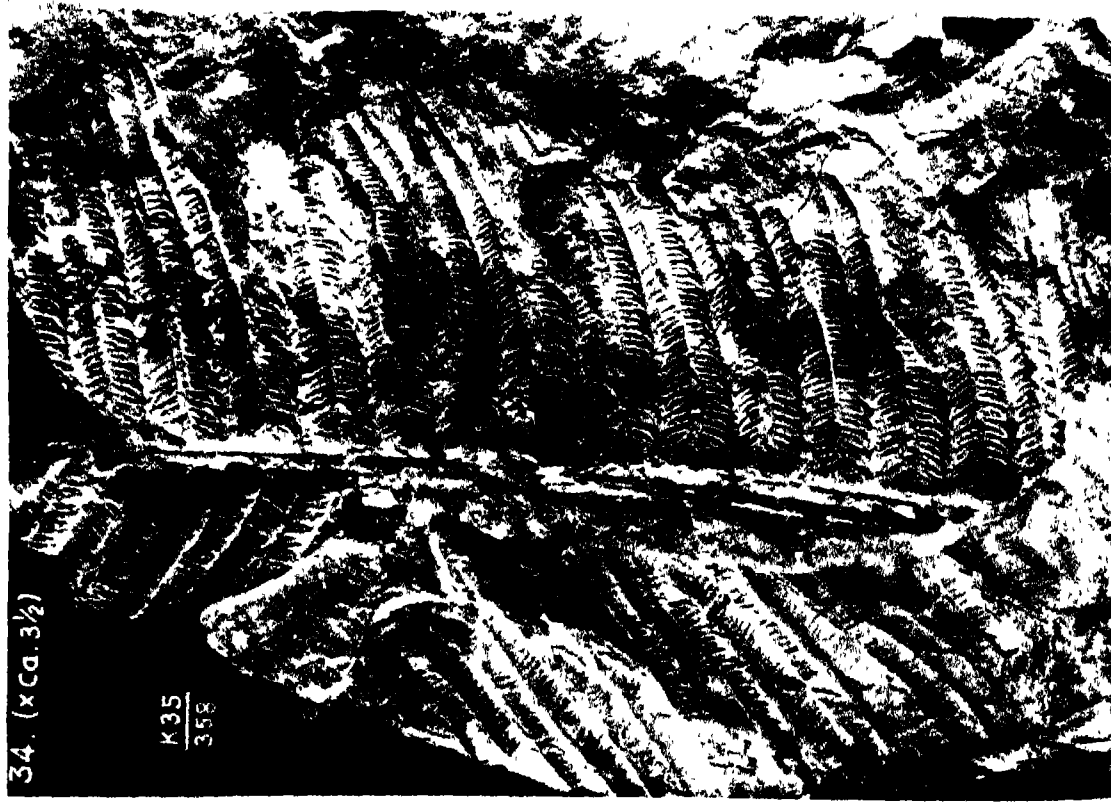
26. (x Ca. 3)

V. S. Photos.

25-26: *Phlebopteris indica* sp. nov.

27-30: *Cladophlebis* (?*Phlebopteris*) sp. A.





33 (x 1)



37. (x 5)



35. (x ca. 3)



36. (x ca. 5)

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# PROCEEDINGS

## OF THE

# NATIONAL ACADEMY OF SCIENCES

## INDIA

### 1945

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97	...	3	2	appartus	apparatus
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98	...	1	6	Whittleseyinean	Whittleseyinaean
99	...	1	5	169, 173	169—173
101	I, 1, a, i, 2	...	...	Spore	Spore 2
103	Spore 26	...	...	arms long	arms short
103	..	...	...	tubercles rather large	tubercles comparatively stout and closely arranged
103	II, 2, a, i	...	...	grauular	granular
103	Spore 37	...	...	1/5 1/6	1/5—1/6
104	Spore 43	...	...	Spor	Spore
106	IV	...	...	FOUR	THREE
106	IV, 1, b, i	...	...	? lobed	three lobed
106	Below subheading	...	...	28	18
107	Spore 1	1	1	324 $\mu$	32.4 $\mu$
108	Spore 5	2	4	sam	same
111	Spore 45	1	1	triral	trira—
111	Spore 45	3	1	resembe	resemble
111	Spore 45	3	3	elliptica	elliptical
112	Spore 49	3	1	57	47
112	Spore 51	2	2	47	147
112	Spore 53	1	4	95 $\mu$ + 76 $\mu$	95 $\mu$ $\times$ 76 $\mu$
113	Spore 64	...	...	(III, 1,...)	(III, 1...)

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113	Spore 67			(III, 1.. )	(III, 1...)
114	Spore 87	4	4	..	Add after fig. 5 "The structure of the cuticle of <i>Glossoptris communis</i> Feistmantel (to be published later)"
115	Spore 1	2	3	13	14
115	Spore 30	2	• 3	3	4
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118	...	1	1	spore	spores
120	..	1	1	p.	p. 137
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120	Spore 23	1	1	32 $\mu$ $\times$ 40 $\mu$	32 $\mu$ — 40 $\mu$
120	Spore 23	4	1	describes	described
120	..	4	2	p.	p. 129
121	Spore 32	...	.	(II, i...)	(II, 1.. )
122	Spore 51	1	2	p.	p. 112
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125	Spore 84	2	1	190-191, B,	190B, 191
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125	..	1	2	2,	22,
125	..	2	4	...	see correction above, p 114.
125	..	2	5	14	13
125	Spore 95	1	1	attachment	attachment
127	.	1	2	63	33
129	Spore 23	1	1	p.	p. 129
130	Spore 34	...	...	(II, i...)	(II, 1.. )
132	Spore 64	2	2	Kathwi	Kathwal
132	..	2	2	35	56
132	Spore 66	1	3	axis	axes

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133	Description of	text-figs.	1	ext-figs,	Text-figs.
133	"	...	2	he	the
134	Spore 83	3	1	28	58
135	Spore 85	2	3	190 A	190 A, 193, 194
135	Spore 87	3	4	...	see correction above, p. 114
139	Spore 87	2	4	...	see correction above, p. 114
140	Spore 43	3	2	pl. 18, fig. 142	Pl. 1, fig. 4—For reference see correction above, p. 114
141	Spore 49	1	2	29 $\mu$	129 $\mu$
142	Spore 81	3	4	that	than
143	Spore 85	2	3	Newcastle	Newcastle
143	"	2	3	190,	190 A,
143	Spore 87	...	.	Pl. 1, figs. 4, 5	see correction above, p. 114.
143	Spore 88	2	2	p.	p. 155
143	Below subheading	...	...	8	9
146	Spore 7	...	...	(.... ii...)	(.....1...)
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148	Spore 44	1	2	111	112
148	Spore 49	4	2	3	4
148	Spore 50	2	3	185	186
150	Spore 56	3	1	303	152
152	Description	of text-figs.	6	...	After spore 90, add <i>Pityosporites</i> sp.
152	"	...	6	sl. longitudinal slit	delete
152	"	...	7	...	After <i>Pityosporites</i> sp add, sl.—longitudinal slit.
154	Spore 87	3	2	158	168
155	...	1	5	...	see correction above p. 114.
157	Spore 43	2	1	marks	mark
158	...	2	1	45	fig. 45
158	...	2	2	116	fig. 116

Page	Spore	Para.	Line	Errata	Correction
159	...	1	11	...	After structure of, add, the cuticle of. For reference see correction above, p. 114
159	...	1	15	...	After structure of, add, the cuticle of. For reference see correction above, p. 114
160	Spore 84	1	7	Pit S	delete
160	„	3	2	163,	163—
161	...	1	1	close	delete
161	...	1	1	longer	delete
161	Description	of text-fig.	2	42,	42—
161	„		3	width	with
161	„		4	twice	twice
164	Ibrahim	17	1	Aegirhorizonts	Aegirhorizonts
165	Schopf	18	1	...	After Illinois. add "State Geol. Surv Ill."
166	Vareschi	6	1	1835	1935
170	„	Fig. 66	...	big	large
170	„	„	...	s.—l <sub>1</sub> —s—l <sub>4</sub>	sl. <sub>1</sub> —sl. <sub>4</sub>
172	Plate 8	1	2	cuticle	cuticle
174	Plate 12	Fig. 151	2	7	17
175	„	Fig. 170	1	464	44
175	„	Fig. 174	...	43—38	43×38

*The quest for early traces of the *Glossopteris flora**

BY B. SAHNI

In this note I propose to sketch briefly the background of events which led to the important discoveries recorded in the following paper by Dr. Virkki on "Spores from the Lower Gondwanas of India and Australia" (pages 93 ff.)

My aim in suggesting that Dr. Virkki should make a detailed (microscopic) examination of the rocks of the Lower Gondwanas was to see how far down into the Gondwanas it was possible to trace the *Glossopteris flora*.

The question of the climatic relations of this flora has long engaged the attention of palaeobotanists and geologists. The main point at issue was not the sort of climate that supported the rich vegetation of the Barakar and Raniganj periods but the climatic conditions that governed the origin and early history of this flora, which was essentially so distinct from the tropical vegetation then flourishing north of the Tethys barrier. *Prima facie* grounds, e.g., the marked contrast between the two floras geographically separated by an east-west barrier; the relative paucity of the southern flora; the sharply marked growth rings of the southern *Dadoxyla*; and the fact that the distribution of the earliest known plant-bearing beds closely followed that of the glacial boulder bed, all pointed to the idea that the southern flora could not have existed in a tropical climate. But the discovery by T. N. Leslie (1921)\* and later by A. L. du Toit (1924) of *Gangamopteris* immediately below and in contact with the Dwyka tillite in South Africa went further—it proved that at least in that part of Gondwanaland this flora already existed during the glacial period, and in the close vicinity of the ice, like the flora which today fringes the Greenland ice-cap.

On general grounds, therefore, it appeared unlikely that conditions in India, where essentially the same sort of vegetation was known to have existed, could have been very different. But a contrary view has been held, and expressed with some emphasis, by Dr. (now Sir Cyril) Fox, until lately Director of the Geological Survey of India, whose opinions are entitled to the respect that is due to a geologist of his official position. In two memoirs devoted to a detailed stratigraphical study of the Gondwana System and

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\* See Bibliography at the end of Dr. Virkki's paper. -

Related Formations (1931) and the Lower Gondwana Coalfields of India (1934) he has written as follows:

"So pronounced has been the idea of the influence of extreme cold that it is generally concluded that the rise of the *Glossopteris* flora was contemporaneous with this upper Palaeozoic (middle to upper Carboniferous) Ice Age. The conclusion that the *Glossopteris* flora flourished in a cold climate is open to question" 1931 p 7.

"The remains of fossil plants are only found in the topmost beds of the Talchir series." (p.8)

"It has been concluded therefore that *Glossopteris* had already appeared in the great Ice Age of Gondwana times. And it has been presumed from this that the *Glossopteris* flora was able to stand the severe climate of the Glacial epoch, or that this flora was able to develop under conditions of extreme cold." (p.13).

"Now plant remains, very rare indeed, are only found in the topmost beds of the Talchir sediments". (p.13).

"There is no doubt that a *Glossopteris* flora has not been found closely associated with the glacial boulder beds of the Gondwana system. In Kashmir and the Punjab Salt Range the *Gangamopteris* (with *Glossopteris*) horizon occurs at a considerably higher horizon than the Boulder bed. The position of the fossil plants in the Talchir series has been discussed in the previous paragraph. The conclusion is that the climate of the Ice Age was not favorable to the *Glossopteris* flora" (p.14).

Referring to plant fossils in the Talchir series he says (1934 p.12)

"Such occurrences are always at the top of the series and well above the boulder bed".

In view of these definite expressions of opinion, so directly opposed to those of several palaeobotanists who have given thought to this problem, including the late Professor Seward, Dr. du Toit, and the writer, it was important to ascertain how far down into the Talchir series it was possible to push our knowledge of the *Glossopteris* flora of India, and in particular to see if we could not find traces of this flora in the glacial matrix itself.

Until as late as 1936 the oldest plant-bearing horizon known in the Lower Gondwanas of India was one at Kathwai, in the Salt Range. This was discovered by Mr. E. R. Gee, who very kindly sent me a collection of plant fossils from a carbonaceous shale exposed about 20-25 ft. above the Talchir Boulder Bed. Although the specimens were nearly all fragmentary, they were worthy of a close examination in view of their low geological horizon. Writing to me on the 20th May 1937, Mr. Gee said

"These Gondwana plant fossils belong to as low an—probably lower—horizon as any previously found in India. As they occurred within 20—25 feet above the Talchir Boulder Bed I especially examined this 20-25 feet of strata for any evidence of a fault or discontinuity, but found none. The sequence was as follows. The Talchir Boulder Bed here

rests directly on the Purple Sandstone Series (Lower Cambrian or pre-Cambrian). The Boulder-bed is here only a foot or two in thickness, consisting of boulders up to over a foot in diameter embedded in a gritty matrix. There is no question about its being the Talchir Boulder-bed of the base of the Speckled Sandstone series. This boulder bearing sandstone passes up into a gritty greyish or greenish-grey sandstone which includes some shaly bands, carbonaceous in the upper part. The latter passes up into sandy grey shales with carbonaceous bands and these into the black carbonaceous shales containing the plants."

After a cursory examination, which showed several typical Gondwana forms, species of *Glossopteris* and *Gangamopteris*, *Sphenopteris*, *Cardiocarpus*, *Samaropsis* and a new *Ottokaria*, the collection was passed on to Miss Virkki for a careful investigation, *particularly of the cuticles and any microfossils in the rock-matrix*. This search revealed the existence of numerous spores in the rock, obviously belonging to early members of the *Glossopteris* flora, *the number of distinct spore types being far greater than the number of species of macrofossils*. This fact suggested that even the supposedly sterile shales lower down in the Talchir series would, if subjected to micro-analysis, reveal at least wind-borne traces of any vegetation that might then have existed and which, falling upon lakes and streams, might have been entrapped in the sediments. I therefore suggested to Miss Virkki to make a close search for microfossils in strata lower and lower down in the series, preferably in the very section which Mr Gee had examined, which appeared to me to be a particularly suitable section for pursuing a search for the beginnings of the *Glossopteris* flora in the Punjab. This search was richly rewarded, as will be seen from the numerous spores figured from horizons as low as  $1\frac{1}{2}$  and  $4\frac{1}{2}$  feet above the boulder bed at Kathwai.

Further, from the analogy of Dr. V. Vareschi's work on the microflora of modern glacier ice (1935) I imagined that *even the matrix of the Talchir Boulder Bed itself might be expected to contain at least microscopic traces of fossils* for, as on modern glaciers, wind-borne organic dust must have fallen upon the glaciers and ice sheets of Gondwanaland, and under those cold conditions must have had exceptionally favourable conditions for being preserved in the ancient moraines. \* In January 1938 I wrote (p. 16)

"To prove that the flora actually co-existed with the ice it only remains to demonstrate these spores within the glacial matrix itself, and I think the facts at hand fully justify the expectation that this will be done. An investigation of the spore content of the glacial matrix not only in the Salt Range but in other parts of Gondwana Land, is thus full of interesting possibilities.

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\* The moraines left by Pleistocene and Recent glaciers and icesheets must also, of course, be expected to contain microfossil remains of contemporary plants and animals, but these have not attracted so much attention, presumably because they do not afford detailed chronological data in the same way as the strata of ice, or varved lake sediments, do.



Miss Virkki was therefore advised to examine samples of the fine-grained matrix of the Boulder Bed at Kathwai, and requests were sent out to colleagues abroad for similar samples from other Gondwana tillites, particularly those in South Africa and in Australia. The Kathwai sample of tillite did not yield any evidence of microfossils, but a piece of the well known Bacchus Marsh tillite in Victoria (Australia) received through the kindness of Mr. W.N. Edwards, Keeper of Geology at the British Museum, revealed a large number of spores similar to some already known from the carbonaceous shales of the 1½ft., 4½ft. and 20-25 ft. horizons at Kathwai. Samples of the Dwyka tillite kindly sent me by the late Dr T. N. Leslie and by Dr. du Toit were also examined by Dr. R.V. Sitholey with interesting results; and Mr. D.D. Pant has made a detailed study of both the Dwyka and the Bacchus Marsh material with a surprisingly rich haul of microfossils.

Until quite recently all attempts to discover microfossils in the Indian Gondwana tillites had consistently failed. But from a compact calcareous shaly horizon within the Talchir Boulder Bed exposed near Chittidil, in the Salt Range, from which I had collected some material in October 1945, I was able to prepare some woody tissues as well as spores, which I hope to describe elsewhere.

These evidences of fossil plants within the matrix of the glacial boulder bed of the Gondwanas prove conclusively that the *Glossopteris flora* co-existed with the ice in India, as it did in Australia and South Africa. The facts do not lend any support to the view, repeatedly advanced without any real evidence by Sir Cyril Fox, that the climate of the Ice Age was not favourable to the *Glossopteris flora*.

Probably no one, except perhaps Sir Cyril, now entertains any doubt on this matter. In its initial stage the *Glossopteris flora* must have been a cold temperate flora; and it would be no surprise if we should later be led to the conclusion, which I have elsewhere tentatively ventured (1937 p. 59; 1938 p. 18) that the origin of this southern flora was in some way causally connected with the advent of the Gondwana cold wave.



## NOTE.

The work embodied in the following paper was carried out during the years 1937-39, while the author was a research student at the University of Lucknow. Unfortunately its publication has been seriously delayed, for reasons given below. Meanwhile other microfossil investigations on the Gondwana rocks carried out in this laboratory have been published, either in full or in preliminary reports.

The MS was sent to the Geological Survey of India on 1 December 1940 and was accepted for publication as a Memoir in the *Palaeontologia Indica*. The blocks of the photographic illustrations were prepared, the plates were printed off at the Geological Survey office in Calcutta and the galley proofs were ready by September 1941. On 16 April 1942, however, the entire work was returned to me by Sir Cyril Fox, along with a series of other palaeobotanical papers which had likewise been accepted for the *Palaeontologia Indica*. Owing to war conditions all scientific publications had been suspended by the Survey. The text thus had to be re-edited and the material re-arranged for publication in the *Proceedings of the National Academy of Sciences*. By arrangement with the Geological Survey it has, however, been possible to make use of the half-tone plates originally prepared for the larger format of the *Palaeontologia Indica*.

LUCKNOW,  
16th April 1946.

B. S.

# SPORES FROM THE LOWER GONDWANAS OF INDIA AND AUSTRALIA\*

BY C. VIRKKI (MRS. C JACOB), Ph.D.,

RESEARCH FELLOW DEPARTMENT OF BOTANY, UNIVERSITY OF LUCKNOW.

(With 15 Plates and numerous Text figures)

(Communicated by Professor B. Sahni, F.G.S., F.R.S.)

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\*Part of a thesis approved in 1940 for the degree of Doctor of Philosophy at the University of Lucknow.

\*  
ABSTRACT.

This paper deals with spores and other organic remains obtained from the Lower Gondwana rocks of five localities in India and two in Australia. The spores from each horizon are treated in a separate section

Schulze's maceration fluid ( $\text{HNO}_3$  and  $\text{KClO}_3$ ) was ordinarily used. When the shales were not very hard, water was quite sufficient to disintegrate the rock

A natural classification of the spores is at present not practicable. Therefore, another artificial classification had to be preferred. In this classification importance is given to the characters of the wing

It was found difficult to apply the nomenclature proposed by the earlier authors. For convenience the spores are named *Spore 1*, *Spore 2*, etc.

A key to the classification of these spores is given and the descriptive terminology employed is explained.

The first section deals with the spores from the beds 1½ ft. above the Talchir Boulder bed exposed at Kathwai. The locality, horizon and the material are discussed. Fifteen kinds of spores are described from this horizon

The second section deals with the spores from a horizon just 4½ ft. above the Talchir Boulder bed. The age of the bed and the nature of the material are not far different from those of the 1½ ft. horizon. The spores obtained from this section are very badly preserved and descriptions of only seven kinds of spores are given.

The spores from the 20-25 ft. horizon of the same locality are treated in the third section. The age of these beds is discussed in a different paper. Twenty-six kinds of spores from this horizon are described

In the fourth section spores from the plant beds just below the Middle Productus Limestone at Warchha are treated. The age of the beds is discussed elsewhere. Thirty kinds of spores and a piece of tracheid are dealt with in this section.

The fifth section deals with six kinds of spores obtained from the plant beds just below the Middle Productus Limestone at Jhallowali

Descriptions of fifteen kinds of spores and a piece of tracheid are given in the sixth section, which deals with the spores from the Lower Barakar beds of the Daltongunj coalfield in Bihar. The locality and horizon are discussed in a separate paper.

In the seventh section the age of the Pali beds in Rewa is discussed. Descriptions of thirty-four different kinds of spores, a bit of a tracheid and a cuticle are given.

The eighth section deals with the spores obtained from the glacial tillite at Bacchus Marsh, Victoria. Eight kinds of spores, a bit of a tracheid and certain animal remains are described in this section.

In the ninth and last section two kinds of spores (*Pityosporites seawardi* and *Pityosporites* sp.) obtained from a Permo-Carboniferous shale from Newcastle, N. S. W., are briefly described

There is a continuous transition from the one-winged type of spores to the two-winged type (*Spore 42* to *Spore 60*). The relation of the *Glossopteris* flora to the glacial conglomerate is discussed at the end of the paper. On the basis of the available evidence it is concluded that the *Glossopteris* flora existed during the Ice Age, if not earlier.

## INTRODUCTION.

Of late the investigation of fossil spores has become a rapidly growing study in several parts of the world. A survey of the series of papers by Erdtman (1927, pp. 196-211; 1930, pp. 191-213; 1932, pp. 395-418; 1934, pp. 463-481; 1935, pp. 261-274; 1937, pp. 157-181), on the "Literature of Pollen-statistics" gives an idea of the vast amount of work that is being turned out at present.

It is needless to say that this line of study has considerable botanical, geological and economic importance. The reproductive organs, specially the spores, of many of the fossils that remained undiscovered came to light by the microscopic study of coal and other deposits. The geological importance of this work is shown by the fact that the correlation of coal-seams based on their microscopic contents has received considerable attention from workers in various parts of the world. (Elovski, 1930; Ergolskaia, 1930; Naumova, 1937, n. 60, *Paget*, 1936; *Luber*, 1937, p. 61; *Raistrick and Simpson*, 1933, pp. 1-11; *Raistrick*, 1934, pp. 1-13; 1938, pp. 221-226; *Trueman*, 1938, pp. 257-269; *Slater, Evans and Eddy*, 1930; *Slater*, 1932, pp. 1-18; *Thiessen and Staud*, 1924). The importance of microfossil studies in the correlation of coal seams in India has been indicated in a recent communication by Professor Sahní (1941, pp. 581-582).

Spores of living plants also have attracted the attention of Wodehouse (1935, pp. 1-574); Knox (1938, pp. 438-466); Erdtman (1937, pp. 185-196); Vareschi (1935; 1937, pp. 17-35); and others. Erdtman's paper (1937, pp. 185-196) "Pollen-grains recovered from the atmosphere over the Atlantic" gives an idea of the wide distribution of spores through the agency of wind. Recently Vareschi (1935, pp. 83, 84), has demonstrated that the spores of recent plants which settle down on the surface of glaciers ultimately reach the depths of the glacier, forming chronological zones in the ice.

In India practically no work on fossil spores had been done so far except on the Pleistocene pollen of Kashmir by Wodehouse (1935); and the Tertiary pollen of certain carbonaceous shales of Assam by Ghosh (1941, p. 674). The present work was started on spores accidentally discovered in the shales about 20-25 ft. above the Talchir Boulder bed, exposed in a section at Kathwai in the Salt Range (*Virkki*, 1937, pp. 428-431; 1938, pp. 150, 151).

At the suggestion of Professor Sahní a visit was paid to the Salt Range with the hope that spores might be found in horizons lower than the lowest

plant-bearing horizons so far recorded. As anticipated by him, the search for spores in the shales collected from 1½ ft. and 4½ ft., respectively, above the Talchir Boulder bed, proved quite successful, although the glacial matrix itself gave a negative result. Nevertheless, the presence of spores in the shales 1½ ft. above the glacial bed strengthened his view that spores may be present in the actual glacial deposit itself, though not of the Salt Range, perhaps of other parts of Gondwana Land. Professor Sahni surmised that since Vareschi had found spores preserved in the ice of the modern glaciers, there was no reason why they could not be found in the Permo-Carboniferous glacial deposits, if plants then existed in the vicinity of the ice.

Accordingly, at the request of Professor Sahni samples of Permo-Carboniferous tillites were kindly sent from certain localities in Australia and Africa. Most of them were found to contain no spores, but a sample of tillite from Bacchus Marsh, Victoria, sent by the authorities of the British Museum, yielded various types of spores as well as a few tracheids and certain other organic remains (*Virkki, 1939, pp. 7-12*).

#### LOCALITIES AND HORIZONS.

The spores from the Lower Gondwanas of India and Australia were obtained from different localities, five in India and two in Australia.

##### *India.*

Kathwai, Salt Range, Punjab.

Warchha, Salt Range, Punjab.

Jhallelwāli, Salt Range, Punjab.

Daltongunj coalfield, Palamau district, Bihar.

Pali beds, Rewa.

##### *Australia.*

Bacchus Marsh, Victoria.

Newcastle, New South Wales.

The spores from each horizon are treated under a separate section. Details about the locality, horizon, material, etc., will therefore be given separately under each section.

#### TECHNIQUE.

Schulze's maceration fluid ( $\text{HNO}_3 + \text{KClO}_3$ ) was ordinarily used. In rare cases when the material was very hard hydrofluoric acid was used to crumble the rock. Most of the dark shales from the Salt Range and Rewa were easily disintegrated in water.

When the spores were prepared there was no intention of a quantitative study. The spores from the various localities do not give a representative idea of the Lower Gondwana flora of that particular horizon. The samples from the various horizons, especially those from 1½ ft. and 4½ ft., respectively, above the Talchir Boulder bed in the Salt Range, and those from Australia (glacial tillite) were too insufficient in quantity. The spores from Jhaliewali represent only those obtained during maceration of the cuticle. Some spores might have been lost in manipulation.

#### CLASSIFICATION.

A natural classification of the spores is almost impossible at present. None of those described here was found in organic connection with any other plant remains. Although some are adhering to the surface of the cuticle of certain species of *Glossopteris*, no definite conclusions can be drawn regarding their affinities. Almost all the spores are preserved in a flattened condition, thus making it extremely difficult to determine their original form and size.

The classification of the spores should be based on their most constant characters. Many authors have taken the germinal apparatus as the decisive feature. Wodehouse (1935, p. 156) is of opinion that "The form and character of the germinal furrows are generally rather strictly phyletic, tending to be constant throughout families and other large groups." Accordingly he bases his classification on the nature of the germinal apparatus, but even this feature shows great variations in the Coniferales. Again the same type of furrow may be present in totally different groups, for example, in the Ginkgoales and the Cycadales.

Lyuber, Valtz and Naumova (1937, p. 60.) also have given prominence to the slit; but I am unable to follow their classification as I have not seen their detailed papers.

There are many difficulties in giving prominence to the slit in the case of fossil spores. Some of them may be mentioned here.

In the first place, it is not always easy to differentiate between a furrow and a tetrad mark, when both are present. In the lower plants, like the ferns, the tetrad mark or slit on the proximal side of the spore takes over the function of the germinal apparatus. In higher plants, where the tetrad mark is indistinct or completely eliminated in the mature pollen-grains, the furrow or the germ pore on the distal side functions as the germinal apparatus. Between these two types (spores and pollen-grains), according to



Schopf (1938, pp. 14, 15) there is the "prepollen", which is a pollen in the sense it has a furrow and it is primitive as the furrow is still on the proximal side. He takes the genus *Monoletes* as an example of this type. *Monoletes* was instituted by Ibrahim (1933) as a provisional name for spores having one dehiscence mark and bilateral symmetry. Schopf, (1936, pp. 107-110; 1938 pp. 44, 46) adopted it for spores of the type of the Whittleseyinean fructifications (Halle, 1933, pp. 8-67). When describing *Monoletes ovatus* (Schopf 1938, pp. 44, 45; Pl. 1, figs. 3-5; Pl. 6, figs. 1-4) he says the longitudinal streak is the furrow on the proximal side and the folds are round it on the same side. On the other hand, Florin (1937, pp. 312-317, 326-331; Pl. 2, figs. 3-5; Pl. 3, figs. 1, 3, 4, 6-8) in his description of the spores of the various members of the Whittleseyinae, calls the streak on the proximal side as the tetrad mark. He is of opinion that the fold seen round the slit is on the distal side, and it represents the fold round the broad, long germinal furrow. Halle gives another interpretation to the streak and the two folds on the surface of the spores of the Whittleseyinae. In the description of the spores of *Goldenbergia glomerata*, Halle (1933, p. 11; Pl. 2, figs. 13-17) interprets the two folds as "the junction between the part of the wall facing outwards in the tetrad and the two radial walls", and the median line (streak) as the "angle between the two radial walls". Nevertheless, he admits that the spore might have opened there on germination; for in some cases slits were observed instead of the streak. Renault (1896, pp. 266, 268) considered the two folds of *Dolerotheca* as two furrows. Wodehouse (1935, p. 226, fig. 69A) disagrees with Renault in this interpretation and suggests that these two furrows are the two grooves which form at the sides of the single deep furrow.

Thus we see that different authors are not in agreement in interpreting the longitudinal streak and the fold.

The majority of the spores are seen only in one view, where the slit may not be visible. Bad preservation also may have obliterated all traces of the slit.

From the paper by Knox (1938, pp. 438-466) which deals with spores chiefly of the living Pteridophyta, we find that the sculpturing is of specific importance, with certain exceptions. According to her within the Selaginellaceae (Knox 1938, pp. 442, 443, figs 10-25) there are spores both of the smooth-walled and the warty type, with intergradations of spinous and tuberculate.

In fossil spores too much confidence cannot be placed on the sculpturing, as this character may not be well-preserved.

My aim in classification is to make it convenient for description: it is not claimed that the classification adopted here is a natural one. Accordingly, the

presence or absence of wings has been taken as the main feature on which the classification is based. Further, from a study of spores, both living and fossil, it is found that the wing should also be taken as one of the constant features of spores. For example, Lycopodiales have unwinged spores with exceptions like *Spencerites insignis* (Scott 1920, pp. 169, 173; figs. 78 A, B 84), *Selaginella Parkeri*, *S. rupestris* and *S. megastachys* (Knox 1938, p. 443; figs. 23-25). In the Pteridosperms the microspores are unwinged; those in the Cordaitales have one wing; and the pollen-grains in the Coniferales sometimes have characteristic bladders. Exceptions are found in all the groups.

According to Wodehouse (1935, p. 254) "the bladdery wings constitute a character that was originally quite separate from and far more ancient than the ancient furrow with which it is always associated among the modern spermatophytes." Next to the wing importance is given to the slit.

The classification followed here has its own limitations, and in no way is it claimed to be the last word on the classification of spores.

#### NOMENCLATURE.

The nomenclature of isolated spores is as confusing as their classification. Each author follows his own method of naming the spores. Many of them use the name *Pollenites*, to distinguish microspores from *Sporites* (megaspores), followed by the specific name proposed by the author and preceded by the generic name if that is known. Wodehouse (1933, p. 432) in describing spores from the recent deposits, names them by adding the suffix *pites* (an abbreviation of *Pollenites*) to the specific designation if the genus of the pollen species is known or to the genus if that is uncertain.

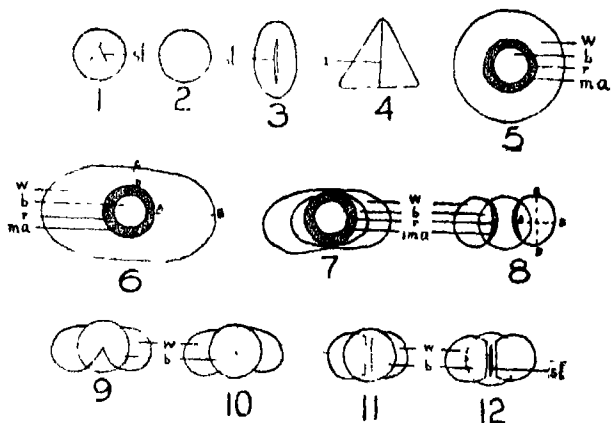
According to the classification adopted by Lyuber, Valtz and Naumova (1937, p. 60) the spores are divided into three groups, (a) *Triletes*, (b) *Monoletes* and (c) *Aletes*. According to the presence or absence of the margin each group is again subdivided into genera, e.g. (a) *Zonotriletes*, (b) *Azonotriletes*, etc. The sub-groups are further divided into species as *Azonotriletes punctulatus*.

I am reluctant to apply the nomenclature proposed by these authors to the spores described in this paper, and I do not propose adding to the confusion. A more exhaustive study of spores appears to be necessary before giving definite names to them.

To avoid some of the difficulties of nomenclature, the spores are provisionally called *Spore 1*, *Spore 2*, etc. The group to which each belongs is denoted by the abbreviations following it, for example, *Spore 1* (*I*, *1*, *a*, *i*, (*I*)),

where *I*, stands for unwinged; *l*, no slit; *a*, smooth or granular surface; *i*, round or roundly triangular, thin or thick-walled, and (*l*) round thin wall (see below for a key to the classification).

As stated before, this very artificial (even arbitrary), scheme of classification has its own limitations; that is to say, all spores under *Spore 1* need not necessarily be of the same species.



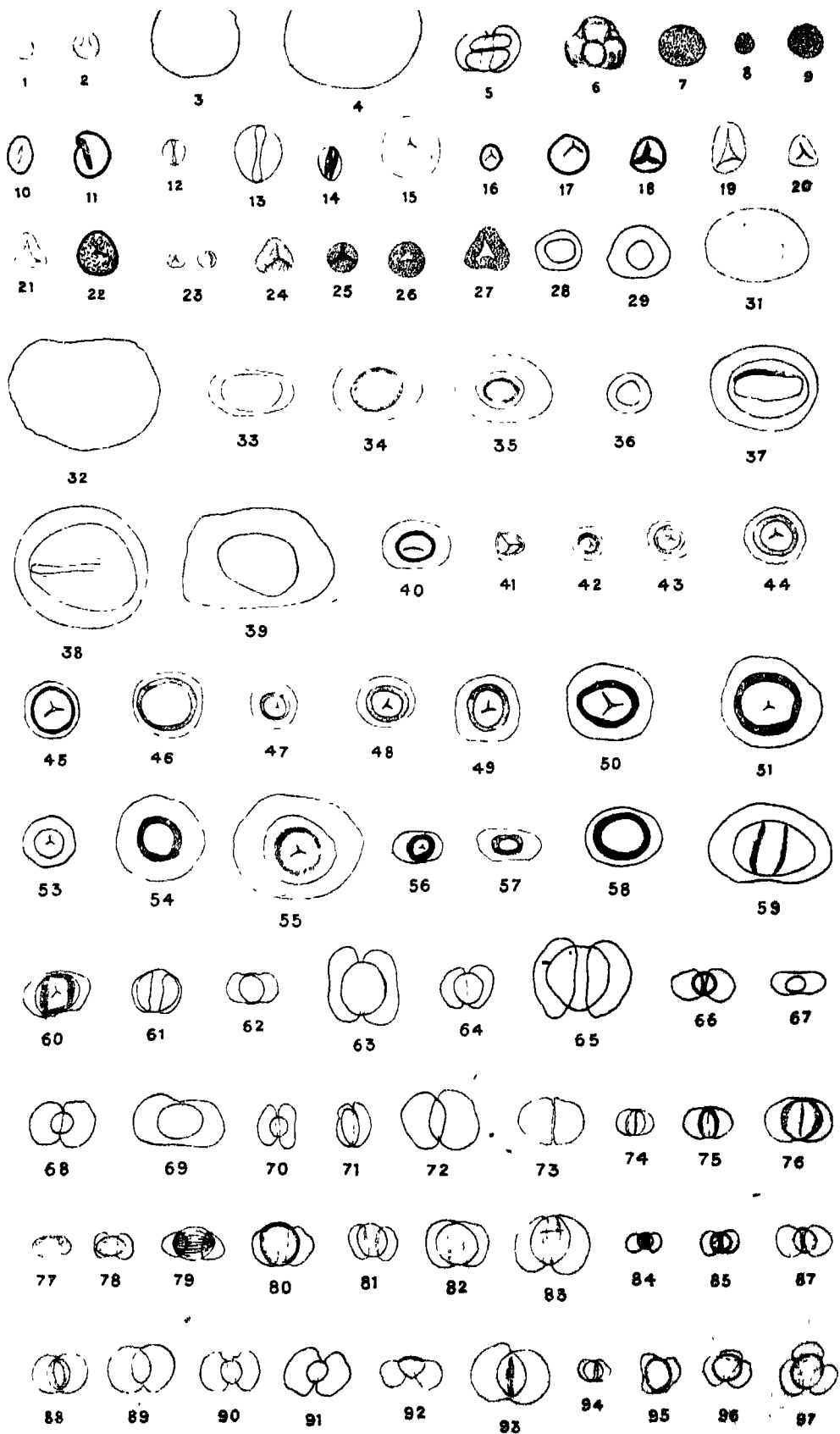
Text-figs 1—12. Diagrammatic drawings of spores to explain the special terms used in their description. *a*.—axis; *b*.—body; *A. . B.*—line representing the transverse axis of the wing; *C. . D.*—line representing its vertical axis; *i. m. a.*—intramarginal attachment of the wing; *m. a.*—marginal attachment; *r.*—rim; *sl*—slit; *w.*—wing; Figs. 1, 8, 11—proximal side (dorsal view); figs. 2, 12—distal side (ventral view); figs. 9, 10—lateral view.

#### DESCRIPTIVE TERMINOLOGY USED.

To follow the description of the spores more easily an attempt is made here to explain the special terms used.

The spores are brought down to us in the flattened condition and, therefore, only the outline form is given in the description. In the case of the triangular spores the measurements are given of the median (the line joining an angle to the middle of the opposite side), which is termed the *axis* (Text-fig. 4 *a*). The *slit* refers to the opening on the surface of the spores, which might indicate either the tetrad mark (*sl* in Text-figs. 1, 8) or the furrow (*sl* in Text-fig. 12), as the case may be. As defined by Wodehouse (1935, p. 542), the *furrow* is "a longitudinal groove or opening in the exine, either enclosing a germ pore or serving directly as the place of emission of the pollen tube, also generally serving as a harmomegathus" (a mechanism which accommodates a semi-rigid exine to changes in volume), and the *germ*





porus is "a pollen-tube anlage or the place of emergence of the pollen tube, generally denoted by a rounded papilla."

In some of the one-winged spores a thickening is seen round the body (*r.* in Text-figs. 5-7). This is termed the *rim*, and it is generally found associated with the wing. This corresponds to the thickening seen in the case of the two-winged spores (Text-fig. 8, *r.*)

When the spore is one-winged and when the wing is not of uniform width, the axis represented by the line *A—B* in Text-fig. 6 is termed the *transverse axis* while *C—D* is the *vertical axis*. The same terms are used in the case of the two-winged spores (Text-fig. 8 *A—B* ; *C—D*).

Generally, spores can be viewed in three or four different planes. The side towards the tetrad is the *proximal side* (Text-figs. 1, 3, 11) and when viewed from this side the spore presents the *dorsal view*. The tetrad mark when present is seen in this view (*sl.* in Text-figs. 1, 3). The side opposite the proximal is the *distal side*. The view of the spore is then the *ventral view* (Text-figs. 2, 12). Text-figs. 9, 10 represent the two *lateral views*.

The attachment of the wing may be either *marginal* (when it gets free from the margin of the body) as seen in Text-figs. 5, 6 (*m.a.*) or *intra-marginal* (when the wing is free before it reaches the margin—*i.m.a.* in Text-figs. 7, 8).

# KEY TO THE CLASSIFICATION.

*N.B.*—See outline sketches in Text-fig. 13. The measurements are given in  $\mu$ .

## I. UNWINGED.

### 1. NO SLIT.

#### a. Smooth or granular—

##### i. Round to roundly triangular; smooth; wall thin or thick; longest axis 20-60:

- |  |     |     |          |
|--|-----|-----|----------|
| (1) Round to broadly elliptical; wall thin; 25-50  | ... | ... | Spore 1. |
| (2) Round or roundly triangular; wall thick; 40-60 | ... | ... | Spore    |

##### ii. Broadly elliptical; granular; wall thin; 140-250 long:

- |                   |     |     |     |          |
|-------------------|-----|-----|-----|----------|
| (1) Less than 200 | ... | ... | ... | Spore 3. |
| (2) More than 200 | ... | ... | ... | Spore 4. |

##### iii. Bilateral tetrads; elliptical to reniform; granular; wall thick:

- |                 |     |     |     |          |
|-----------------|-----|-----|-----|----------|
| (1) 60-100 long | ... | ... | ... | Spore 5. |
|-----------------|-----|-----|-----|----------|

##### iv. Lobed; smooth; wall thick:

- |                     |     |     |     |          |
|---------------------|-----|-----|-----|----------|
| (1) Eight lobed; 50 | ... | ... | ... | Spore 6. |
|---------------------|-----|-----|-----|----------|

Text-fig. 13.—Outline sketches of spores to accompany the key to the classification.

All magnified 95 diameters except Spore 55 ( $\times 98$ ) and Spore 52 ( $\times 100$ ). The numbers below each figure indicate those of spores in the descriptive part. Spore 50, Spore 53 and Spore 56 are not figured.

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## b. Spinous—

i. Round or roundly triangular; spines long, pointed; 20-70:

- |  |     |     |     |          |
|--|-----|-----|-----|----------|
| (1) Approximately round; wall thin; ca. 70 | ... | ... | ... | Spore 7. |
| (2) Roundly triangular; ca. 30-50          | ... | ..  | ..  | Spore 8  |

## c. Tuberculate—

i. Round; tubercles small;

- |        |     |     |     |     |          |
|--------|-----|-----|-----|-----|----------|
| (1) 56 | ... | ... | ... | ... | Spore 9. |
|--------|-----|-----|-----|-----|----------|

## 2. ELONGATED SLIT.

## a. Slit with tapering ends—

i. Round to elliptical; elongated slit or fold; smooth; wall thick:

- |   |     |     |           |
|---|-----|-----|-----------|
| (1) Elliptical; slit 2/3 the length of spore; 65-85 | ... | ... | Spore 10  |
| (2) Approximately round; longitudinal fold; 80-80   | ... | ... | Spore 11. |

## b. Slit with bulging ends—

i. Spherical to oblate; slit as long as the spore, ends bulging; smooth or faintly granular; wall thin; 40-90:

- |  |     |     |     |           |
|--|-----|-----|-----|-----------|
| (1) Approximately round; 40×41         | ... | ... | ... | Spore 12. |
| (2) Round to broadly elliptical; 80-90 | ... | ... | ... | Spore 13. |

## c. Slit with thickened margin—

i. Elliptical; slit as long as the spore, margin thick, flap-like; smooth or faintly granular; wall thin:

- |                 |     |     |     |     |           |
|-----------------|-----|-----|-----|-----|-----------|
| (1) Spore 56×38 | ... | ... | ... | ... | Spore 14. |
|-----------------|-----|-----|-----|-----|-----------|

## 3. TRIRADIATE SLIT.

## a. Smooth or granular—

i. Round; triradiate slit, arms short; folds on the surface; finely granular; wall thin:

- |               |     |     |     |     |          |
|---------------|-----|-----|-----|-----|----------|
| (1) 104.5×102 | ... | ... | ... | ... | Spore 15 |
|---------------|-----|-----|-----|-----|----------|

ii. Roundly triangular; knob at one angle; triradiate slit or thickening; smooth; wall thick:

- |                               |     |     |     |           |
|-------------------------------|-----|-----|-----|-----------|
| (1) Triradiate slit; 40×38    | ... | ... | ... | Spore 16  |
| (2) Triradiate slit; 68       | ... | ... | ... | Spore 17. |
| (3) Triradiate thickening; 58 | ... | ... | ... | Spore 18. |

iii. Elliptically triangular; triradiate cavity, arms reaching to the angles:

- |                     |     |     |     |           |
|---------------------|-----|-----|-----|-----------|
| (1) Longest axis 80 | ... | ... | ... | Spore 19. |
|---------------------|-----|-----|-----|-----------|

iv. Triangular; knob present or not; triradiate slit, arms short; smooth; wall thin:

- |           |     |     |     |     |           |
|-----------|-----|-----|-----|-----|-----------|
| (1) 50-70 | ... | ... | ... | ... | Spore 20. |
|-----------|-----|-----|-----|-----|-----------|

v. Triangular; triradiate cavity, arms reach to the angles, margins thickened; smooth; wall thin:

- |             |     |     |     |     |           |
|-------------|-----|-----|-----|-----|-----------|
| (1) Axis 62 | ... | ... | ... | ... | Spore 21. |
|-------------|-----|-----|-----|-----|-----------|

## b. Wrinkled—

i. Round to angular; triradiate fold; wrinkled, wall thick:

- |             |     |     |     |     |           |
|-------------|-----|-----|-----|-----|-----------|
| (1) Axis 74 | ... | ... | ... | ... | Spore 22. |
|-------------|-----|-----|-----|-----|-----------|

## c. Spinous—

i. Round to angular; triradiate slit; arms short; folds in some cases;

- |           |     |     |     |     |           |
|-----------|-----|-----|-----|-----|-----------|
| (1) 28-40 | ... | ... | ... | ... | Spore 23. |
|-----------|-----|-----|-----|-----|-----------|

ii. Triangular; triradiate slit, arms long; spines comparatively long:

(1) Axis 64 ... .. Spore 24.

**d Tuberculate—**

i. Round; triradiate thickening, arms reach to the margin; tubercles short, in close concentric circles:

(1) 50 ... .. Spore 25.

ii. Triangular; triradiate cavity, arms long, margin thickened; tubercles rather large:

(1) 60 ... .. Spore 26.

iii. Triangular; triradiate cavity, arms long, margin thickened; tubercles rather large:

(1) 68 ... .. Spore 27.

**II. ONE-WINGED.**

**1. No SLIT.**

**a. Body round—**

i Spore approximately round; body round, dark, granular; wing  $\frac{1}{2}$  to  $\frac{1}{3}$  the diameter of the body, coarsely granular:

(1) Wing  $\frac{1}{2}$  the diam of body; spore 77×64 ... .. Spore 28.

(2) Wing  $\frac{1}{3}$  the diam. of body; spore 96×92 ... .. Spore 29.

**b. Body elliptical—**

i. Spore elliptical; outline of body not clear; wing slightly pitted:

(1) Spore 188 long ... .. Spore 30.

(2) Spore 168 long ... .. Spore 31.

(3) Spore 253 long ... .. Spore 32

ii. Spore elliptical; body thin walled; wing finely granular:

(1) Spore 146 long ... .. Spore 33.

iii. Spore elliptical; body thick walled; wing coarsely granular:

(1) Spore 157-168 long ... .. Spore 34.

iv Spore elliptical; body dark; attachment of the wing intra-marginal, slightly pitted:

(1) Spore 150 long ... .. Spore 35

**c. Body triangular—**

i. Spore round; body roundly triangular, dark; wing radially striated:

(1) 71 in diameter ... .. Spore 36.

**2. ELONGATED SLIT.**

**a. Slit long and broad—**

i. Spore round to elliptical; wall thin; wing coarsely granular:

(1) Elliptical; slit long and broad; wing  $\frac{1}{3}$   $\frac{1}{8}$  the length of the body; spore 184 long ... .. Spore 37.

(2) Round to broadly elliptical; slit long and narrow; spore 230-270 long ... .. Spore 38.

(3) Broadly elliptical; wing  $\frac{1}{2}$  the length of the body; spore 227 long... Spore 39.

**b. Slit crescent-shaped—**

i. Spore elliptical; body elliptical; rim thick; wing coarsely granular:

(1) Spore 110-120 long ... .. Spore 40.



## 3. TRIRADIATE SLIT.

a. *Wing flat*—

- i. Spore roundly triangular; body roundly triangular; triradiate mark, arms extend to the margin; wall thick; wing flat, convoluted:

(1) Axis 50 ... .. Spore 41.

b. *Wing bladder-like*—

- i. Spore round to elliptical; body round to elliptical; triradiate slit, arms

short; rim thick; wing bladder-like frilled or flat  $\frac{1}{8}$  to  $\frac{1}{2}$  the diameter of the body, tendency to be two winged, attachment marginal or intra-marginal, radially striated:

- (1) Wing frill like, spore 55-70 long ... .. Spore 42.  
 (2) Wing frill like; spore 74-86 long ... .. Spore 43.  
 (3) Wing frill like; spore 90-105 long ... .. Spore 44.  
 (4) Wing flat,  $\frac{1}{8}$  to  $\frac{1}{6}$  the diam. of the body; spore 80-100 long ... Spore 45.  
 (5) Wing flat,  $\frac{1}{6}$  to  $\frac{1}{8}$  the diam. of the body; spore 118 ... Spore 46.  
 (6) Wing flat,  $\frac{1}{4}$  the diam. of body; spore 65-75 ... Spore 47.  
 (7) Wing flat,  $\frac{1}{4}$  the diam. of body; spore 95-110 ... Spore 48.  
 (8) Wing flat,  $\frac{1}{4}$  the diam. of body; 115-120 ... Spore 49.  
 (9) Wing flat,  $\frac{1}{4}$  the diam. of body; spore 140-150 ... Spore 50.  
 (10) Wing flat,  $\frac{1}{4}$  the diam. of body; spore 170-180 ... Spore 51.  
 (11) Wing flat,  $\frac{1}{4}$  the diam. of body, spore 234 ... Spore 52.  
 (12) Wing flat,  $\frac{1}{4}$  the diam. of body; spore 78-92 ... Spore 53.  
 (13) Wing flat,  $\frac{1}{4}$  the diam. of body; spore 146 ... Spore 54.  
 (14) Wing flat,  $\frac{1}{4}$  the diam. of body; spore 228 ... Spore 55.  
 (15) Spore elliptical; body round; vertical axis of the wing  $\frac{1}{8}$  the transverse diameter of the body; spore 80-105 ... Spore 56.  
 (16) Spore elliptical; body round; vertical axis of the wing  $\frac{1}{7}$  the transverse diameter of the body; spore 110 ... Spore 57.  
 (17) Spore elliptical; body round; vertical axis of the wing  $\frac{1}{9}$  the transverse diameter of the body; spore 182 ... Spore 58.  
 (18) Spore elliptical; body round; transverse axis much longer than vertical, attachment of the wing on either side intra-marginal, pronounced tendency to be double winged; spore 197 ... Spore 59.  
 (19) Same as above; wing above and below a little more reduced; spore 107 ... Spore 60.

## III. TWO-WINGED.

## 1. NO SLIT.

a. *Body round*—

- i. Transverse axis of wing  $\frac{1}{2}$  and vertical axis more or less same as that of the body:

(1) Body 74×60; wing 32×62 ... .. Spore 61

ii. Transverse axis of wing  $\frac{1}{2}$  and vertical axis  $\frac{1}{5}$  that of the body:

- (1) Body 42; wing 22×50 ... Spore 62.  
 iii. Transverse axis of wing  $\frac{1}{2}$  and vertical axis  $1\frac{1}{2}$  times that of the body:  
 (1) Body 88×80; wing 58×120 ... Spore 63.

iv. Transverse axis same, vertical axis  $1\frac{1}{2}$  times that of the body; wings reniform:

- (1) Body 40-60; t.a. 35-60, v.a. 60-85 ... Spore 64.  
 (2) Body 100; t.a. 70-100; v.a. 124-150 ... Spore 65.  
 v. Transverse axis and vertical axis  $1\frac{1}{2}$  times that of the body:  
 (1) Body 32-48; t.a. and v.a. 45-60 ... Spore 66.

vi. Transverse axis twice and vertical axis  $1\frac{1}{2}$  times that of the body; wing fused or separate:

- (1) Body 84×22; wing 44×38 ... Spore 67.  
 (2) Body 84-42; t.a. 60-80; v.a. 50-70 ... Spore 68.  
 (3) Body 62-80; t.a. 100; v.a. 77 ... Spore 69.  
 vii. Transverse axis  $1\frac{1}{2}$  and vertical axis thrice that of the body:  
 (1) Body 24×38; wing 38×68 ... Spore 70.

b. *Body elliptical*—

i. Wings attached parallel to the body; body broadly elliptical:

- (1) Body 34×54; wing 39×70 ... Spore 71.

ii. Wings attached parallel to the body; body narrowly elliptical:

- (1) Body 26×58; wing 63×91 ... Spore 72.

iii. Wings attached at right angles to the body; body broadly elliptical:

- (1) Body 100×60; wing 55×76 ... Spore 73

2. ELONGATED SLIT.

a. *Slit with tapering ends*—

i. Body not striped, round to elliptical; slit long and vertical; wings not differentiated from each other, pitted:

- (1) Body elliptical in the vertical plane; 26×49 ... Spore 74.  
 (2) Body elliptical in the vertical plane; 28×47 ... Spore 75.  
 (3) Body round; 68×67 ... Spore 76.

ii. Body striped, triangular in lateral view, round or broadly elliptical in ventral view, wall thick; wing bladder-like, transverse axis  $\frac{1}{2}$  to  $1\frac{1}{2}$  times that of the body—*Pitucosporites*:

- (1) Transverse axis of wing  $\frac{1}{2}$  that of body; body 86×32; t.a. wing 18 Spore 77.  
 (2) Transverse axis of wing  $\frac{1}{2}$  that of body; body 50×32; t.a. wing 26 Spore 78.  
 (3) Transverse axis of wing  $\frac{1}{2}$  that of body; body 70×60; t.a. wing 41 Spore 79.  
 (4) Transverse axis of wing  $\frac{1}{2}$  that of body; body 69; t.a. wing 50 ... Spore 80.  
 (5) Transverse axis of wing  $\frac{1}{2}$  that of body; body 42×54; t.a. wing 27×39 Spore 81.  
 (6) Transverse axis of wing  $\frac{1}{2}$  that of body; body 58×67; t.a. wing 41×44 ... Spore 82.  
 (7) Transverse axis of wing  $\frac{1}{2}$  that of body; body 74×80; t.a. wing 48×60 ... Spore 83.

- (8) Transverse axis of wing same as that of body; body  $26 \times 27$ ; t.a. wing  $23 \times 30$  ... Spore 84.
- (9) Transverse axis of wing same as that of body; body  $22 \times 32$ ; t.a. wing 34 ... Spore 85.
- (10) Transverse axis of wing same as that of body; body 35; t.a. wing 27 ... Spore 86.
- (11) Transverse axis of wing same as that of body; body  $40 \times 62$ ; t.a. wing  $40 \times 58$  ... Spore 87.
- (12) Transverse axis of wing  $1\frac{1}{2}$  times that of body, wings fused; body  $30 \times 37$ ; t.a. wing  $45 \times 47$  ... Spore 88.
- (13) Transverse axis of wing  $1\frac{1}{2}$  times that of body, wings fused; body  $42 \times 50$ ; t.a. wing 55 ... Spore 89.
- (14) Transverse axis of wing  $1\frac{1}{2}$  times that of body, wings fused; body  $38 \times 43$ ; t.a. wing 47 ... Spore 90.
- (15) Transverse axis of wing  $1\frac{1}{2}$  times that of body; body round to elliptical  $30 \times 44$ ; t.a. wing  $56 \times 76$  ... Spore 91.
- (16) Transverse axis of wing  $1\frac{1}{2}$  times that of body; body triangular,  $40$ ; t.a. wing 56 ... Spore 92.
- b. Slit with thickened margin—
- i. Body elliptical, slit as long as the body, thickened on the margin, like an operculum; wing considerably bigger than the body:
- (1) Body  $48 \times 60$ , wing  $66 \times 87$  ... Spore 93.

## IV. FOUR-WINGED.

## 1. No SLIT.

## a. Body spherical—

## i. Wings three, attached on the sides, equidistant, surface pitted:

- (1) Body  $30 \times 44$ ; t.a. wing 27 ... Spore 94

## b. Body flattened—

## i. Body round, margin thickened; wings ?lobed:

- (1) Body,  $58 \times 46$ ; t.a. wing 17 ... Spore 95

## ii. Body round, margin thick; wings separate, attachment intra-marginal:

- (1) Body 50, t.a. wing 29 ... Spore 96.

## iii. Body elliptical, longitudinally and transversely striped, dark; wings radially striated:

- (1) Body  $60 \times 48$ ; t.a. wing 38 ... Spore 97.

## DESCRIPTION.

1. SPORES FROM  $1\frac{1}{2}$  FT. ABOVE THE TALCHIR BOULDER BED, KATHWAI, SALI RANGE.

Pls. 1, 2; Text-figs. 14-28.

*Locality and horizon:* Figs. 1, 2, give an idea of the section exposed at Kathwai of the Talchir Boulder bed (B.) resting directly on the Purple

Sandstone (*p.s.*). The alternate bands of sandstones (*s.s.*) and thin layers of carbonaceous shales (*c.s.*) above the Boulder bed, which form the base of the Speckled Sandstone series, are also clearly seen. It is from these shales 1½ ft. above the Talchir Boulder bed (marked × in fig. 1) that the spores were obtained.

One of the boulders of the glacial conglomerate along with the sandy matrix collected from Kathwai was sent to Mr. D. N. Wadia for confirmation. In a letter to Professor Sahni, dated 12th November 1937, he expresses the opinion that "The specimen labelled 'Talchir boulder', though not a typical one, is evidently derived originally from the boulder-bed. The matrix, however, suggests that the boulder was collected not from the boulder-bed proper, but from a newer bed overlying it—for the matrix is definitely not glacial, but ordinary elastic sandy sediment. This is important, because the glacial matrix of the Talchir boulder-bed of the Salt Range is a highly characteristic dense sticky clay. I think the specimens belong to a stratum composed of *reassorted* Talchir boulders and pebbles overlying the glacial bed. The difference in age, however, is not likely to be considerable."

Mr. E. R. Gee, however, stated in a letter to Professor Sahni that the glacial matrix is gritty.

Regarding the age of this low horizon Professor Sahni (1938, p. 16), writes "the interval represented by the overlying 1½ feet of sediments must have been so short that the lowermost of the spore-bearing horizons may be taken to be approximately of the same geological age as the glacial bed."

*Material.*—The dark shales from this horizon are comparatively fragile. No plant impressions could be found on these shales, except for some indefinite marks: the spores were numerous, but badly preserved.

#### UNWINGED SPORES.

Spore 1 (I, 1, *a*, i, (1).)

Pl. 1, fig. 3.

Spore approximately round; surface smooth; wall thin,  $324\mu \times 28\mu$ .

Spore 1 from the 4½ ft. horizon (Pl. 3, fig. 24), the Pali beds (Pl. 10, fig. 12c) and Bacchus Marsh (Pl. 14, fig. 178) are slightly bigger than the one just described here. Their shape too is somewhat different. This may be due to either the presence of folds on the surface or bad preservation. It does not mean that all these spores belong to the same species or even to the same genus. Owing to their similarity in structure they are grouped together.

Occurrence:—

4½ ft. horizon, Kathwai, Pl. 3, fig. 24.

Pali beds, Rewa, Pl. 10, fig. 128.

Glacial tillite, Bacchus Marsh, Pl. 14, fig. 178.

Spore 5 (I. 1, a, iii, (1) ).

Pl. 1, figs. 4, 5.

Spores in bilateral tetrads; individual spores of either similar shape and size or not, shape of an individual oval to reniform; surface finely granulated; wall thick (not seen in tetrads), radially striated. Average individual  $70\mu \times 35\mu$ ; wall  $7\mu$  thick.

These spores have a striking similarity to *Spore 5* from the 20-25 ft. horizon (Pl. 3, figs. 31, 32) and Warchha (Pl. 6, figs. 63, 64), in their tetrad formation and the shape, size and structure of an average spore. It is possible that these spores belong to plants of at least the same genus, if not the same species.

Occurrence:—

20-25 ft. horizon, Kathwai, Pl. 3, figs. 31-33.

Warchha, Pl. 6, figs. 63-65.

Spore 13 (I. 2, b, i, (2) ).

Pl. 1, figs. 6, 7.

Spore round to broadly elliptical; surface faintly granular; wall thin; longitudinal slit extending to the wall of the spore, ends bulged out and rounded.

The following are the measurements:—

Fig.	Body.
6	$90\mu \times 85\mu$ .
7	$82\mu \times 82\mu$ .

These two spores resemble *Spore 12* from the 20-25 ft. horizon of Kathwai (Pl. 3, fig. 35) except in size.

Our spores can be compared to a certain extent to those of the Bennettitales, (Wodehouse 1935, p. 227) especially in their characteristic longitudinal slit. The prothallial tissue, which, according to Wodehouse, is also characteristic of the Bennettitalean spore, is not observed in ours. In size too the

latter are slightly bigger than the Bennettitalean spore, which ranges from  $20\mu$  to  $67\mu$ .

We cannot but notice a resemblance of the spore in Pl. 1, fig. 6 with the spore of *Cycas*, ( *Wodehouse 1935, p 236; fig. 76A, a* ), but the latter are evidently smaller than our spores. It may be rash on my part to draw any close comparison of our fossil spores with those of the Cycadales. However, it is not unreasonable to think that our spores belong to the Cycadophyta.

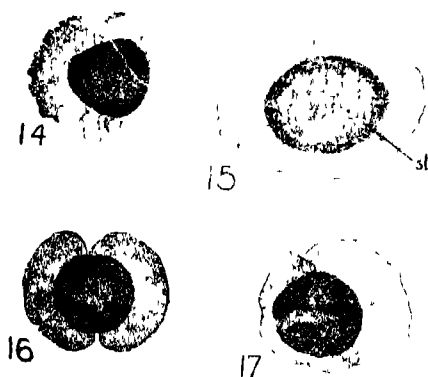
#### ONE-WINGED SPORES.

Spore 36 (II, 1, c, i, (1)).

Pl. 1, fig 8; Text-fig. 14.

Spore round; body roundly triangular, very dark; wing frill-like, radially striated Diameter of spore (including wing)  $71\mu$ ; axis of body  $44\mu$ .

The body is slightly broken on one side.



Text-figs. 14—17. Camera lucida drawings of some of the spores from the 1½ ft. horizon, Kathwal, all  $\times 250$ . Fig. 14—Spore 36, also shown in Pl. I. fig. 8. Fig. 15—Spore 40, *sl.*-slit: the clear space below it is probably a fracture of the body (Pl. I, fig. 9). Fig. 16.—Spore 64, (Pl. II, fig. 17). Fig. 17.—Spore 64, shown in Pl. II, fig. 18.

Spore 40 (II, 2, b, i, (1) ).

Pl. 1, fig. 9, Text-fig. 15.

Spore elliptical; body elliptical; slit (fig. 9, *sl.*; Text-fig. 15, *sl.*) narrow and crescent shaped; surface smooth or faintly granular; rim thick; transverse axis of the wing more than the vertical axis, radial striation faintly marked.\* Body  $66\mu \times 50\mu$ ; rim  $8\mu$ ; transverse axis of the wing  $22\mu$  vertical axis  $15\mu$ .

In size, shape and structure this spore resembles *Spore 40* from Warchha represented in Pl. 6, fig. 80.

Occurrence:—

Warchha, Pl. 6 fig. 80.

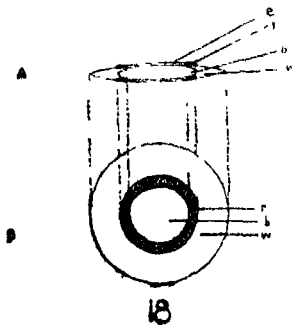
Spore 42 (II, 3, b, i, (1)).

Pl. 2, fig. 10; Text-fig 18.

Spore broadly elliptical; body broadly elliptical, dark; triradiate mark not seen; rim thick; wing bladder-like, frilled and radially striated. Spore  $68\mu \times 52\mu$ ; body  $56\mu \times 38\mu$ ; rim  $10\mu$ .

This spore can be compared with *Spore 42* from Rewa shown in Pl. 11, fig. 140, which is more round. The triradiate mark is also clear.

All the spores referable to *Spore 42* to *Spore 60* (see above key to the classification) show a remarkable resemblance with each other in their fundamental features, such as, the round or elliptical body with a triradiate slit, the thick rim, and the frilled or flat wing extending all round the body (equatorial). The characters by which the individual species is distinguished are the size of the spore, the nature of the wings, whether frilled or flat, and the proportionate size of the body to the wing



Text-fig. 18. Reconstructed drawing of the cross-section (A) of one of the one-winged spores (B) from the groups *Spore 42-Spore 60*. b.-body; e.-exine; r.-rim; w.-wing.

Repeated attempts were made in vain to study the spores by swelling in caustic soda. Microtome sections would have helped the detailed study of the spores; but it was difficult to get them together in large quantities.

These spores recall those of *Spencerites*, (Kubart, 1909, pp. 1-7) or *S. membranaceus*; Scott 1920, pp. 169, 173, figs. 78A, B, 84 for *S. insignis*), where the body is slightly flattened and the wing is bladder-like. A reconstructed cross-

section of the spore may not be far different from what is shown in Text-fig. 18A. The wing (*W.*) is interpreted here as an extension of the exine (*e.*), the body (*b.*) being partly flattened. From where the exine gets free from the body to form the wing, a thickening is seen (*r.*), which can be compared with that seen in some of the two-winged spores (Pl. 6, fig. 86; Pl. 7, fig. 104; Pl. 8, figs 120-122).

To a certain extent these one-winged spores also recall the abnormal spore of *Pinus sylvestris* figured by Florin (1936, pp. 638, 639; Text fig. 4, c-e). Here instead of the two lateral wings placed on either side of the longitudinal furrow on its distal side, there is a single air-sac completely encircling the grain and placed distally without covering the proximal side. The dorsal view of such a spore will appear somewhat like the one-winged spore described above. Nevertheless, it appears more probable that our spores are constructed on the *Spencerites* type rather than on the abnormal type of the *Pinus* pollen; for, almost all the one-winged spores present the same structure.

A species of *Podocarpus*, *P. macrophyllus*, (Wodehouse 1935, p. 277, fig. 79a), where in some cases the body of the pollen completely encircled by a frill, is also known.

Occurrence:—

Pali beds, Rewa, Pl. 11, fig. 140.

Spore 45 (II. 3, b, i, (4).

Pl. 2, figs. 11, 12.

Spores round to broadly elliptical; body round to broadly elliptical; trilateral slit clear; rim thick; wing flat,  $\frac{1}{2}$  the diameter of the body, radially striated.

Following are the measurements:—

Fig.	Spore.	Body.	Rim.
11	88 $\mu$	64 $\mu$	4 $\mu$ .
12	97 $\mu$ × 79 $\mu$	79 $\mu$ × 57 $\mu$	4 $\mu$ .

Spores in figs. 11, 12 are placed in the same species, as they resemble each other in their general structure, except for slight differences in shape and size. Fig. 12 seems to have been round in shape, which now looks elliptical due, presumably, to bad preservation.

Occurrence:—

4 $\frac{1}{2}$  ft. horizon, Kathwai, Pl. 3, fig. 27.

Daitongunj coalfield, Bihar, Pl. 8, figs. 118-115.



Spore 47 (II, 3, b, i, (6)).

Pl. 2, fig. 13.

Spore round; body round; triradiate mark not clear in the photograph; rim thick; wing flat,  $\frac{1}{4}$  the diameter of the body. Spore  $74\mu$ ; body  $50\mu$ ; rim  $6\mu$ .

This spore is already figured in a previous communication. (Virkki, 1939, Pl. 1, fig. 6; Text-fig. e.)

Occurrence:—

$4\frac{1}{2}$  ft. horizon, Kathwai, Pl. 3, fig. 28.

Spore 49 (II, 3, b, i (8) ).

Pl. 2, fig. 14.

Spore similar to the above except for a difference in size. Spore  $101\mu \times 98\mu$ ; body  $64\mu \times 61\mu$ ; rim  $7\mu$ .

The body and the triradiate slit are tolerably well-preserved; but the wing seems to be transparent, probably due to bad preservation.

Occurrence:—

20-25 ft. horizon, Kathwai, Pl. 4, figs. 46, 57.

Daltongunj coalfield, Bihar, Pl. 8, fig. 117.

Pali beds, Rewa, Pl. 11, figs. 143-145.

Glacial tillite, Bacchus Marsh, Pl. 14, fig. 185.

Spore 51 (II, 3, b, i, (10) ).

Pl. 2, fig. 15.

Spore similar to the one just described except for its decidedly larger size. Spore  $172\mu$ ; body  $124\mu \times 97\mu$ ; rim  $8\mu$ .

Occurrence:—

20-25 ft. horizon, Kathwai, Pl. 4, fig. 48.

Pali beds, Rewa, Pl. 12, fig. 47.

Spore 58 (II, 3, b, i, (17) ).

Pl. 2, fig. 16.

Spore broadly elliptical; body approximately round; triradiate slit not clearly visible; rim thick; transverse axis of the wing longer than its vertical axis ( $\frac{1}{4}$  the transverse diameter of the body), radially striated. Body  $95\mu + 76\mu$ ; rim  $11\mu$ ; transverse axis of the wing  $22\mu$ ; vertical axis  $10\mu$ .

The spore resembles those previously described in such features as the broad rim and the radially striated wing; but here a tendency is seen for the vertical axis of the wing to get shorter than the transverse axis. The spore, therefore, offers a transition to the two-winged type.

## TWO-WINGED SPORES.

Spore 64 (III, i, a, iv, (1)).

Pl. 2, figs. 17-19; Text-figs. 16, 17.

Body approximately round, very dark; wings two, transverse axis same and vertical axis  $1\frac{1}{2}$  times that of the body, reniform in shape.

Following are the measurements of the spores:—

Fig.	Body.	Transverse axis (wing).	Vertical axis (wing).
17 . . . .	41.5 $\mu$	35 $\mu$	60 $\mu$ .
18 . . . .	45 $\mu$	38 $\mu$	70 $\mu$ .
19 . . . .	56 $\mu \times 42\mu$	45 $\mu$	70 $\mu$ .

Sometimes the body of the spore seems to be split up into segments (fig 19). This may be due to bad preservation.

The spore in fig. 17 is slightly smaller than the other two. As the difference in size is not very marked it is placed in the same 'species'.

Occurrence:—

20-25 ft. horizon, Kathwai Pl. 5, fig. 55,

Warchha Pl. 6, fig. 84.

Spore 67 (III, i, a, vi, (1)).

Pl. 2, fig. 20.

Body approximately round; wings two, not clearly demarcated from each other, transverse axis twice and vertical axis nearly  $1\frac{1}{2}$  times that of the body. Body 34 $\mu \times 22\mu$ ; transverse axis of the wing 44 $\mu$ ; vertical axis 38 $\mu$ .

Both the wings appear to be fused above and below the body. This might mean that there is actual fusion of the two wings or that the dorsal view of the spore is presented to us.

## PITYOSPORITES Seward.

Spore 86 (III, 2, a, ii, (10) ), *Pityosporites* sp.

Pl. 2, fig. 21.

Body elliptical, stripes not clearly seen in the photograph, transverse axis of the wing nearly same as that of the body. Body  $35\mu \times 26\mu$  ; transverse axis of the wing  $27\mu$ .

Occurrence :—

Pali beds, Rewa, Pl. 13, fig. 167.

Spore 87 (III, 2, a, ii, (11) ), *Pityosporites* sp.

Pl. 2, figs. 22, 23.

The spores in the above figures were already briefly described and figured in a previous communication (Virkki 1937, p 428 ; Pl, XXXII, fig. 3 A, B.) as *Pityosporites* sp. Both the spores present their ventral views.

Body round to elliptical ; stripes six in number ; longitudinal slit seen in the spore represented in fig. 23 ; transverse axis of the wing same as that of the body.

Measurements of the spores are as follow :—

Fig.	Body.	Transverse axis (wing).
22	$42\mu \times 40\mu$	$37\mu$ .
23	$45\mu \times 40\mu$	$3\mu$ .

This spore is removed from Spore 86 on account of its larger size.

Occurrence :—

20-25 ft. horizon, Kathwai, Pl. 5, fig. 60.

Warchha Pl. 7, figs. 94, 95.

Jhallelwari Pl. 7, fig. 105.

Daltongunj coalfield, Bihar Pl. 1, figs. 4, 5.

Pali beds, Rewa Pl. 13, figs. 168, 172.

2. SPORES FROM  $4\frac{1}{2}$  FT. ABOVE THE TALCHIR BOULDER BED, KATHWAI, SALT RANGE.

Pl. 8, figs. 24-30 ; Text-figs. 19-22.

The shales, from which the spores described in this section were obtained, were collected from beds just  $4\frac{1}{2}$  ft. above the Talchir Boulder bed,

Kathwai (Pl. 1, fig. 1). No attempt is made here to describe the locality, horizon and material as they have already been dealt with in detail above.

#### UNWINGED SPORES.

Spore 1 (I, 1, a, i, (1) ).

Pl. 3, fig. 24.

Description as for *Spore 1* from the 1½ ft. horizon ( Pl. 1, fig. 3), but the present spore is somewhat bigger. The slight difference in shape is probably due to a fold on its right hand side. Spore  $46\mu \times 38\mu$ .

Occurrence :—

1½ ft. horizon, Kathwai, Pl. 1, fig. 3.

Pali beds, Kewa, Pl. 10, fig. 128.

Glacial tillite, Bacchus, Marsh, Pl. 13, fig. 178.

#### ONE-WINGED SPORES.

Spore 30 (II, 1, b, i, (1) ).

Pl. 3, fig. 25.

Spore elliptical ; body hardly recognisable ; wing probably covering the body all round, slightly pitted. Spore  $138\mu \times 98\mu$ .

In all the spores of this type the outline of the body is ill-defined. This spore stands a close comparison with *Spore 31* from the 20-25 ft. horizon Pl. 3 figs. 42, 43 and from Jhallelwari Pl. 7, fig. 102 in its shape and structure ; *Spore 31* is larger in size.

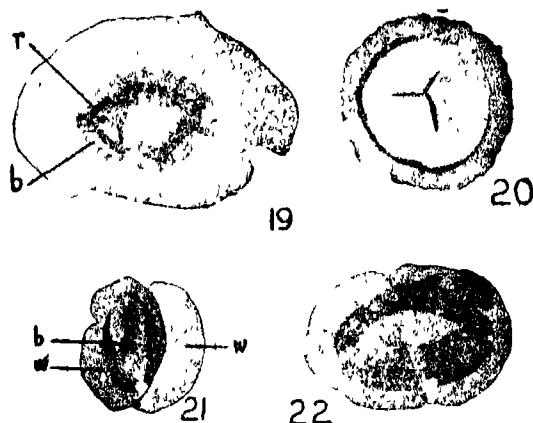
Spore 35 (II, 1, b, iv, (1) ).

Pl. 3, fig. 26, 19.

Spore elliptical ; body (fig. 26, b. ; Text-fig. 19, b.) elliptical, dark, with a broad, dark rim (r.) on the body wall ; wing radially folded and marked with dots (pitted). Spore  $150\mu \times 100\mu$  ; body  $74\mu \times 48\mu$ .

The folds of the wing start from the rim ; this rim may be accidental or may represent the place from where the wing gets free from the body

(intramarginal). It is not possible to say a slit is present, the body being ill preserved.



Text-figs. 19-22. Camera lucida drawings of some of the spores from the 4½ ft. horizon, Kathwai, all  $\times 250$

Fig. 19. *Spore 35*, b.-body; r.-rim. This spore is shown in Pl. III, fig. 26.

Fig. 20. *Spore 45*, triradiate slit is clearly seen (Pl. III, fig. 27).

Fig. 21. *Spore 71*, b.-body; w.-wing, (Pl. III, fig. 29)

Fig. 22. *Spore 73*, body is split. This spore is also shown in Pl. III, fig. 30.

Spore 45 (II, 3, b, i, (4)).

Pl. 3, fig. 27; Text-fig. 20.

Same as *Spore 45* already described above. Spore  $94\mu$ ; body  $74\mu$  rim  $3\mu$ .

This spore is somewhat larger than the one already described. Two arms of the triradiate slit are clear, but the third is partly destroyed.

Occurrence :—

1½ ft. horizon, Kathwai, Pl. 2, figs. 11, 12.

Daltongunj coalfield, Bihar, Pl. 8, figs. 113-115.

Spore 47 (II, 3, b, i, (6)).

Pl. 3, fig. 28.

Spore same as *Spore 47* already described above but slightly smaller; triradiate mark not visible. Spore  $65\mu \times 58\mu$ ; body  $45\mu \times 42\mu$ ; rim  $6\mu$ .

This spore is already figured in a previous communication. Virkki 1939, Pl. I, fig. 7.

Occurrence :—

1½ ft. horizon, Kathwai. Pl. 2, fig. 13.

#### TWO-WINGED SPORES.

Spore 71 (III, 1, b, i. (1) ).

Pl. 3, fig. 29 ; Text-fig. 21,

Body (fig. 29 b. ; Text-fig. 21, b.) elliptical ; wing (*w.*) reniform, finely granulated, faint indications of striations present. Body  $54\mu \times 34\mu$  transverse axis of the wing  $39\mu$  ; vertical axis  $70\mu$ .

The wings are attached to the body on either side parallel to its longer axis. One wing appears to lie over the body.

Spore 73 (III, i, b, iii, (1) ).

Pl. 3, fig. 30 ; Text-fig. 22.

Body broadly elliptical ; wings attached parallel to the shorter axis of the body. Body  $100\mu \times 60\mu$  ; (average wing) transverse axis  $55\mu$  ; vertical axis  $76\mu$ .

#### 3. SPORES FROM 20-25 FT. ABOVE THE TALCHIR BOULDER BED, KATHWAI, SALT RANGE.

Pl. 3, fig. 182—Pl. 5 ; Text-figs. 23-35.

*Locality and horizon.*—The description of the locality, horizon and material will be given in detail elsewhere.

#### UNWINGED SPORES.

Spore 5 (I, 1, a, iii, (1) ).

Pl. 3, figs. 31-33.

Spore 5 has already been described on p. (Pl. 1 figs. 4, 5). Fig. 31 represents a tetrad where the individuals (in two pairs) are of different sizes. The larger spores lying laterally in fig. 31 measure  $68.5\mu \times 42.5\mu$  on an average, while the others are only  $61\mu \times 17\mu$ . Fig. 32 represents a tetrad where the spores are all separated. An individual spore is seen in fig. 33 the position of which is doubtful in this 'species', as it is at least 1½ times larger than the others ; but a reference of the spore to this 'species' is justified on the ground that the individuals of the same tetrad may vary greatly in size.

Measurements of the spore are as follows :—

Fig.	Average of larger spores.	Average of smaller spores.
31 . . . . .	$68.5\mu \times 42.5\mu$	$61\mu \times 17\mu$ .
32 . . . . .	$86\mu \times 36\mu$	$70\mu \times 28\mu$ .
33—body . .	$110\mu \times 59\mu$ ; wall, $15\mu$ .	

Occurrence :—

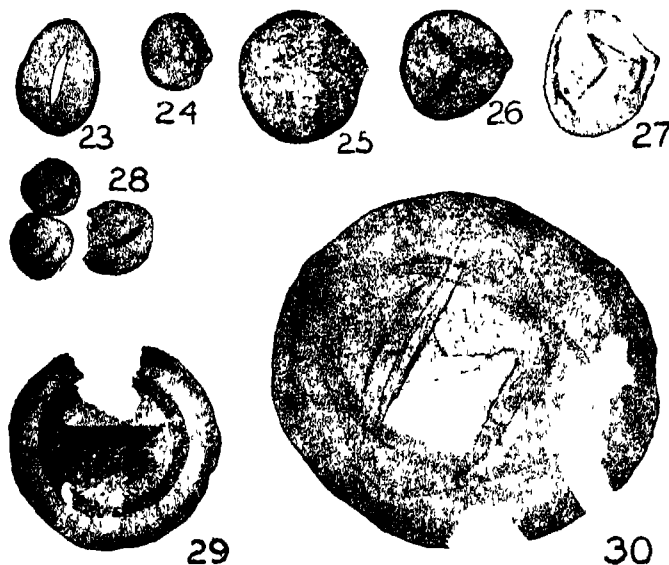
$1\frac{1}{2}$  ft. horizon, Kathwai. Pl. 1, figs. 4, 5.

Warchha. Pl. 6, figs. 63-65.

Spore 10 (I, 2, a, i, (1) ).

Pl. 3, fig. 34, Text-fig 23.

Spore elliptical, length  $65\mu$ — $83\mu$ , breadth  $45\mu$ — $60\mu$  ; slit longitudinal,  $\frac{2}{3}$  the length of the spore, ends tapering ; surface smooth ; wall thick. Spore  $66\mu \times 46\mu$ .



Text. figs. 23-30—Camera lucida drawings of some of the spores of the 20-25 ft. horizon. All  $\times 250$

Fig. 23—*Spore 10*, longitudinal slit with tapering ends is clearly seen (Pl. III, fig. 34). Fig. 24—*Spore 16*, knob on the right side; triradiate slit is a little towards the upper half (Pl. III, fig. 36). Fig. 25—*Spore 17*, triradiate mark is placed towards the lower half (Pl. IV, fig. 37). Fig. 26—*Spore 18*, three thickenings (flaps). This spore is shown in Pl. IV, fig. 38. Fig. 27—*Spore 20*, folds on the body (Pl. IV, fig. 40). Fig. 28—*Spore 23*, triradiate slits in the two smaller spores are shown (Pl. IV, fig. 41).

Fig. 29—*Spore 49*, part of the body is torn and turned over covering two arms of the slit; on the upper half of the body rim is seen as two bands (Pl. IV, fig. 46).

Fig. 30—*Spore 52*, body is not seen; there are two folds lying at right angles to each other; triradiate slit clear (Pl. V, fig. 49).

Spore 12 (I, 2, b, i, (1)).

Pl. 3, fig. 35.

Spore approximately round ; slit longitudinal, as long as the spore, with bulged out and rounded ends; surface faintly granular ; wall thin. Spore  $41\mu \times 40\mu$

This spore resembles *Spore 13* of the  $1\frac{1}{2}$  ft. horizon described above. (Pl. 1, figs. 6, 7) in its shape and characteristic slit, but the former is only half the size of those classed under *Spore 13*.

Spore 16 (I, 3, a, ii (1)).

Pl. 3, fig. 36; Text-fig. 24.

Spore broadly elliptical; knob on one side; triradiate slit clear; surface smooth, or faintly granular; wall thick. Spore  $40\mu \times 38\mu$ ; wall  $3\mu$ .

Spore 17 (I, 3, a, ii (2)).

Pl. 4, fig. 37; Text-fig. 25.

*Spore 17* is more or less similar to *Spore 16* (Pl. 3, fig. 36) except for the larger size of the body and the more rounded form. Spore  $68\mu$ ; wall  $4\mu$ .

The triradiate slit is seen excentrically placed (lower half of the fig.); perhaps this appearance is due to the lie of the spore.

Spore 18 (I, 3, a, ii (3)).

Pl. 4, fig. 38; Text-fig. 26.

Spore more round than angular; three thickenings instead of the slit. Axis  $58\mu$ ; wall  $3\mu$ .

The thickenings appear to be three flaps. The spore resembles *Spore 16* and *Spore 17* in general shape, presence of the knob, smooth surface and thick wall. On account of the difference in the tendency of its body to become angular and the presence of the triradiate thickenings (? flaps), it is classed a different 'species'.

Spore 19 (I, 3, a, iii (1)).

Pl. 4, fig. 39.

Spore elliptically triangular, sides of different length; triradiate cavity, arms reach the margin of the body; surface faintly granular; wall thin. Axes  $80\mu$ ,  $74\mu$ , and  $62\mu$ .

Spore 20 (I, 3, a, iv (1)).

Pl. 4, fig. 40; Text-fig. 27.

Spore roundly triangular; indication of a knob at one angle; triradiate slit clear; surface smooth; wall thin. Longest axis  $67\mu$ .

This spore can be compared with *Spore 20* from Jhallowali described on



p. (Pl. 7, fig. 101). The latter is slightly smaller, and does not show any sign of a knob. However, the other features are common to both and they are placed in the same 'species'. This spore is removed from *Spores 17, 61, and 18*, as the wall is quite thin.

Occurrence:—

Jhallelwari, Pl. 7, fig. 101.

Spore 23 (I, 3, c, i (1)).

Pl. 4, fig. 41; Text-fig. 28.

Spores round; size varying, diameter  $32\mu \times 40\mu$ ; triradiate slit not clear in the largest spore (Text-fig. 28); surface either granular or faintly spinous (cannot be distinguished due to bad preservation), wall thin.

Spores similar to these are very common in the preparation. They are seen to lie in groups or scattered. The folds on the surface of the spore might be accidental, for they are similar in their shape, size and structure to those obtained from the fertile fragment of ?*Alethopteris* sp. from the same horizon.

The fact that similar folds are seen in the spores from the matrix of the shale as well as from the frond shows that they are similar in structure. The extreme thinness of the wall is probably responsible for the formation of the folds. The probability is that these isolated spores, some of which show slight variations in size and shape, belong to the same species and possibly to such fronds as ?*Alethopteris* sp.

These spores can also be compared to *Spore 23* from Warchha describes on p. (Pl. 6, figs. 71-73). The latter resemble the smallest in fig. 41 in their shape, size and general structure.

Occurrence:—

Warchha, Pl. 6, figs. 71-73.

#### ONE-WINGED SPORES.

Spore 31 (II, 1, b, i (2)).

Pl. 4, figs. 42, 43.

These spores resemble *Spore 30* of the  $4\frac{1}{2}$  ft. horizon already described above (Pl. 3, fig. 25) in every respect but in their larger size. They are, therefore, removed to another 'species'.

Measurements are as follow:—

Spore	
Fig.	(including wing).
42	$164\mu \times 123\mu$
43	$166\mu \times 120\mu$

Slight indication of the body is seen in the spore shown in fig. 42

Occurrence: -

Jhallelwari, Pl. 7, fig. 102.

Spore 32 (II, i, b i, (3)).

Pl 4, fig 44.

This badly preserved spore is broadly elliptical; the body is not clearly seen; but the central part of the spore is lighter in colour than the marginal region. Probably the body is destroyed or else it is quite transparent. Spore  $253\mu \times 176\mu$ .

Due to the apparent lack of differentiation between the body and the wing, this spore is referred to the same group as *Spore 90* and *Spore 31*. The marked difference in size has necessitated its removal to another 'species'.

Spore 48 (II, 3, b, i (7)).

Pl 4, fig. 45.

Spore round; body round; triradiate slit not seen in the photograph; rim not clear; wing  $\frac{1}{3}$  the diameter of the body, radially striated Spore  $100\mu$ ; body  $70\mu$ .

This is distinguished from *Spore 47* and *Spore 49*, on account of the difference in size.

This spore has been figured in a previous communication. (*Virkki 1939, Pl. I, fig. 9.*)

Occurrence:—

Daltongunj coalfield, Bihar, Pl. 8, fig. 116.

Glacial tillite, Bacchus Marsh, Pl. 14, fig. 184.

Spore 49 (II, 3, b, i (8)).

Pl. 4, figs 46, 47; Text-fig. 29.

*Spore 49* from the  $1\frac{1}{2}$  ft. horizon (Pl. 2, fig. 14) has already been described.

Measurements are as follow:—

Fig.	Spore.	Body.	Rim.
46	$116\mu \times 110\mu$	$79\mu$	$9\mu$
47	$118\mu$	$83\mu \times 80\mu$	

The spore shown in fig. 46 (Text-fig. 29) is better preserved. The triradiate slit is faint. Part of the body is torn and turned over itself. The rim at this place is seen in two bands.

## Occurrence:—

- 1½ ft. horizon, Kathwai, Pl. 2, fig. 14.  
 Daltongunj coalfield, Bihar, Pl. 8, fig. 117.  
 Pali beds, Rewa, Pl. 11, figs 143-145  
 Glacial tillite, Bacchus Marsh, Pl. 14, fig. 185.

Spore 51 (II, 3, b, i (10)).

Pl. 4, fig. 48

This spore is similar to *Spore 51* from the 1½ ft. horizon, which has already been described on p. (Pl. 2, fig. 15). Spore  $176\mu \times 154\mu$ ; body  $126\mu \times 116\mu$ ; rim  $12\mu$

This spore can also be compared to *Spore 51* from the Pali beds, Rewa.

## Occurrence:—

- 1½ ft. horizon, Kathwai, Pl. 2, fig. 15.  
 Pali beds, Rewa, Pl. 12, fig. 147.

Spore 52 (II, 3, b, i (11)).

Pl. 5, fig. 49; Text-fig. 30.

Spore badly preserved; round;  $234\mu \times 198\mu$  in size.

The margin of the body is not clearly seen. There are two folds in the middle of the spore lying at right angles to each other, probably forming part of the body. The presence of the triradiate slit and the radially striated wing identifies its present position; but the difference in size gives it a place in a different 'species'.

Spore 53 (II, 3, b, i (12)).

Pl. 5, figs. 50, 51.

Spores not well-preserved; round: varying slightly in size; triradiate mark not seen in the photograph; wing  $\frac{1}{2}$  to  $\frac{1}{3}$  the diameter of the body, radially striated

Measurements are as follow:—

Fig.	Spore.	Body,	Rim.
50	$80\mu$	$48\mu$	...
51	$78\mu \times 74\mu$	$42\mu$	$4\mu$

In their shape, size and structure these spores show remarkable resemblance to *Spore 53* from the Pali, beds, Rewa (Pl. 12, figs 148, 149).

## Occurrence:—

The spore represented in fig. 51 is figured in a previous paper. (Virkki, 1939, Pl. I, fig. 8; Text-fig. f).

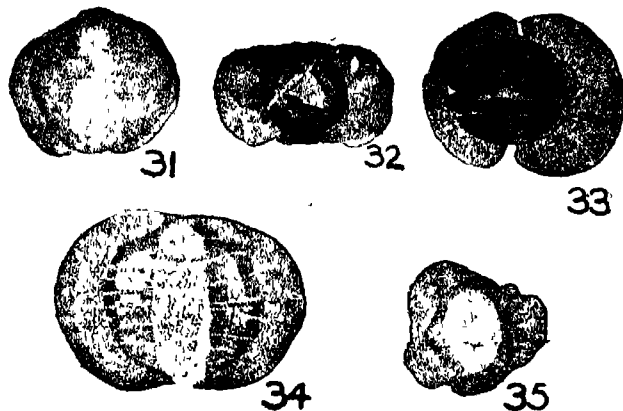
Pali beds, Rewa, Pl. 12, figs. 148, 149.

Spore 54 (II, 3, b, i (13)).

Pl. 5, fig. 52.

Spore round; triradiate mark not preserved. Spore  $146\mu$ ; body  $82\mu \times 74\mu$ ; rim  $10\mu$ .

This spore resembles the one described above in its shape, structure and proportion of the wing to the body. However, this is placed in another 'species' for its difference in size.



Text-figs. 31-35. Camera lucida drawings of some of the spores from the 20-25 ft. horizon, all  $\times 250$  Fig 31. *Spore 61*, two-winged spore (Pl V, fig. 53). Fig 32. *Spore 62*, demarcation of the two wings not clear, clear space in the body may be a fracture (Pl. V, fig 54). Fig. 33. *Spore 64*, body is split into fragments, probably due to the mode of preservation (Pl V, fig. 55) Fig 34. *Spore 83*, *Pityosporites* sp, probably the spore presents the dorsal view; transverse stripes of the body clear (Pl V, fig. 58). Fig. 35. *Spore 95*, three-winged spore, wings not free from each other (Pl. V, fig. 61).

#### TWO-WINGED SPORES.

Spore 61 (III, 1, a, i (1)).

Pl. 5, fig. 53; Text-fig. 31.

Body approximately round; surface finely granular; wall somewhat thick; wings reniform; transverse axis half and vertical axis same as that of the body; radially striated. Body  $74\mu \times 70\mu$ ; transverse axis of the wing  $32\mu$ ; vertical axis  $62\mu$ .

Spore 62 (III, 1, a, iii (1)).

Pl. 5, fig 54; Text-fig. 32.

Body round, very dark, a slit present in the middle of the body (perhaps accidental); transverse axis  $\frac{1}{2}$  and vertical axis  $1\frac{1}{2}$  times that of the

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body, radially striated. Body  $42\mu$ ; transverse axis of the wing  $22\mu$ ; vertical axis  $50\mu$ .

Spore 64 (III, 1, a, iv (1))

Pl. 5, fig. 55; Text-fig. 33

*Spore 64* has already been described above (Pl. 2, figs. 17-19). The spore in fig. 55 is slightly larger than those classed under this 'species'. Body  $63\mu \times 58\mu$ ; transverse axis of the wing  $48\mu$ ; vertical axis  $79\mu$ .

Some cracks are visible on the body which may be due to bad preservation.

Occurrence:

$1\frac{1}{2}$  ft. horizon, Kathwai, Pl. 2, figs. 17-19.

Warchha, Pl. 6, fig. 84

Spore 65 (III, 1, a, iv (?)).

Pl. 5, fig. 56

*Spore 65* similar to *Spore 64* except in size. Body  $107\mu \times 100\mu$ ; transverse axis of the wing  $74\mu$ ; vertical axis  $124\mu$ .

The difference in size is so well marked that it warrants the inclusion of the spore in a different 'species'.

Spore 68 (III, 1, a, vi (2))

Pl. 5, fig. 57.

Spore similar to *Spore 67* from the  $1\frac{1}{2}$  ft. horizon described above (Pl. 2, fig. 20) except in size. Body slightly angular, dark; wings fused above and below with a depression above. Body  $42\mu \times 36\mu$ ; wing  $70\mu \times 74\mu$ .

The depression already mentioned above probably indicates the line of demarcation between the two fused wings.

Occurrence:—

Ball beds, Rewa (Pl. 12, fig. 156).

PITYOSPORITES Seward.

Spore 83 (III, 2, a, ii (7) ). *Pityosporites* sp.

Pl. 5, fig. 58; Text-fig. 34.

Body round, transversely striped; transverse axis of the wing  $\frac{1}{2}$  that of the body. Body  $80\mu$ ; wall  $5.5\mu$ ; transverse axis of the wing  $48\mu$ .

The spore is referred to *Pityosporites* on account of its characteristic structure. The proportion of the body to the wing is quite different from that of *Pityosporites sewardi*, (Virkki, 1937, pp. 428-430; Pl. 32, figs. 1, A-C, 2). Hence this is referred to a different 'species'.

Occurrence:—

Warchha, Pl. 7, fig. 92.

Pali beds, Rewa, Pl. 13, fig. 162.

Spore 84 (III, 2, a, ii (8)), *Pityosporites sewardi*.

Pl. 5, fig. 59.

The spore presents the lateral view. Body slightly triangular, transverse stripes faintly seen, wall thick; transverse axis of the wing same as that of the body. Body  $31\mu \times 27\mu$  wall  $4\mu$ ; transverse axis of an average wing  $3\mu$ .

This spore resembles *Pityosporites sewardi* (Pl. 15, figs. 190-191, B, 192) in its general shape and size. The right wing in fig. 59 is slightly larger than the left; but this may be due to the mode of preservation.

This spore can also be compared with *Pityosporites sewardi* from the Pali beds, Rewa, represented in Pl. 13, figs. 163-165 in shape, size and structure.

Occurrence:—

Pali beds, Rewa, Pl. 13, figs. 163-165.

Permo-Carboniferous shale, Newcastle, Pl. 15, figs. 190 B, 191, 192.

Spore 87 (III, 2, a, ii (11), *Pityosporites* sp.

Pl. 5, fig. 60.

Description of Spore 87 has already been given on p. (Pl. 2, figs. 2, 23). The stripes and thick body wall are clearly seen. Body  $40.5\mu \times 31\mu$ ; wall  $2\mu$ ; transverse axis of the wing  $40\mu$ .

Occurrence:—

1½ ft. horizon, Kathwal, Pl. 2, figs. 22, 23.

Warchha, Pl. 7, figs. 94, 95.

Jhallowalli, Pl. 7, fig. 105.

Daltongunj coalfield, Bihar, Pl. 1, figs. 4, 5.

Pali beds, Rewa, Pl. 14, figs. 168-172.

#### THREE-WINGED SPORES.

Spore 95 (IV, 1, b, i (1)).

Pl. 6, fig. 61; Text.-fig. 35.

Body approximately round; wall fairly thick; wings three, attachment marginal, not free from each other. Body  $58\mu \times 46\mu$ ; average wing  $17\mu$ .

4 SPORES AND OTHER ORGANIC REMAINS FROM JUST BELOW THE  
MIDDLE PRODUCTUS LIMESTONE, WARCHHA, SALT RANGE.

Pls. 6, 7, fig. 99; Text-figs. 36-50.

*Locality and horizon.*—A detailed account of the locality, horizon and material is given in another paper.

## TRACHEID.

Pl. 6, fig. 62

Pl. 6, fig. 62 represents one of the bits of tracheids obtained during maceration of the shale. This piece shows four series of contiguous bordered pits which vary in form from round to almost hexagonal. The pits are mostly alternate, rarely opposite and measure  $10\mu$  in breadth, with a border  $2\mu$  broad. The pores are invariably round. The cells of the medullary rays are not observed.

*Affinities*—The tracheid from Warchha differs from that of *Vertebraria indica* described by Walton and Wilson (1931-1932, p. 202; Pl. 2, figs. 4-7), on many points. The tracheids of *V. indica* have the pits irregularly bordered and the pores are definitely elliptical in shape. Moreover, the pits are slightly flattened and they have a tendency to be arranged in horizontal rows.

In the absence of other internal parts of the wood it is difficult to assign this tracheid to any of the known types of Palaeozoic stems. Two or three series of alternate, hexagonal pits are met with in many Palaeozoic woods.

## UNWINGED SPORES.

Spore 5 (I, 1, a, iii (1)).

Pl. 6, figs. 63-65; Text-fig. 36.

Spore 5 has already been described above (Pl. 1, figs. 4, 5).

Fig. 63 represents a compact tetrad, while fig. 64 represents one which is nearly separating. In fig. 65 is seen a single spore

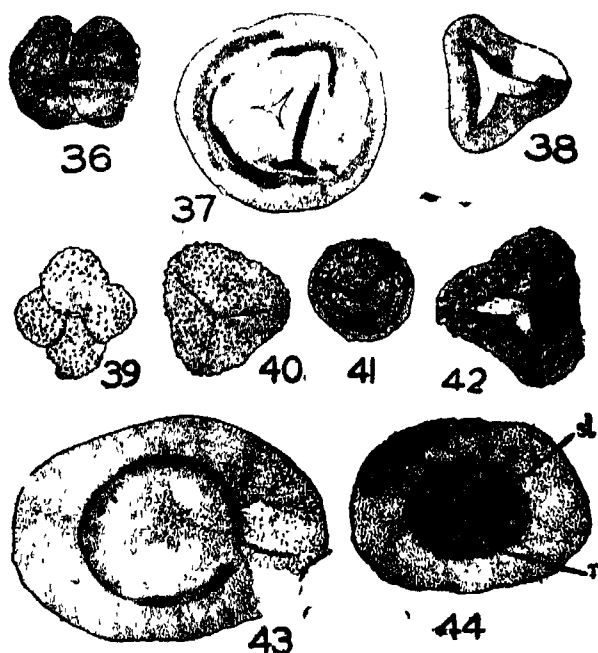
Measurements are as follows:—

Fig.	Average individual.
63	$65\mu \times 33\mu$
64	$53\mu \times 26\mu$
65	$68\mu \times 36\mu$ ; b.w. $1\mu$

Occurrence:—

1½ ft. horizon, Kathwai, Pl. 1, figs. 4-5.

20-25 ft. horizon, Kathwai, Pl. 3, figs. 31-63.



Text-figs. 36-44 Camera lucida drawings of some of the spores from shales just below the Middle Productus Limestone, Warchha, all  $\times 250$ . Fig. 36. *Spore 5*, bilateral tetrad (Pl. VI, fig. 64). Fig. 37. *Spore 15*, the structure of the folds on the body is not clear (Pl. VI, fig. 68). Fig. 38. *Spore 21*, triradial cavity clear (Pl. VI, fig. 69). Fig. 39. *Spore 23*, group of four spores of spinous surface (Pl. VI, fig. 71). Fig. 40. *Spore 24*, surface spinous (Pl. VI, fig. 74). Fig. 41. *Spore 25*, surface tuberculate, tubercles in concentric circles (Pl. VI, fig. 75). Fig. 42. *Spore 27*, surface tuberculate (Pl. VI, fig. 77). Fig. 43. *Spore 34*, shown in Pl. VI, fig. 79. Fig. 44. *Spore 40*, sl.-slit; r.-rim (Pl. VI, fig. 80).

Spore 6 (I, 1, a, iv (1)).

Pl. 6, fig. 66.

The structure of this spore is a little complicated. It appears to be a spore with four large and four small lobes. It is difficult to make out the relative position of each lobe. When focussed lobe 1' (fig. 66,  $l_1$ ) is seen uppermost. Below that lies lobe 2 ( $l_2$ ), which is seen on the upper half of the photograph. Lobe 3 and lobe 4 ( $l_3$ ,  $l_4$ ) are lying on either side. Each lobe shows a dark thick outline on the surface. Lobe 2 and lobe 3 show two transverse folds ( $f$ ). The diameter of each is  $50\mu$ .



Between these larger lobes there are four smaller lobes. The latter ( $s. l_1, s. l_2$ ) between lobe 1 and lobe 3, and lobe 1 and lobe 4 respectively, are seen on either side of lobe 1. Those marked  $s. l_3$  and  $s. l_4$  are faintly seen between lobe 2 and lobe 3, and lobe 4 respectively.

The presence of the smaller lobes definitely shows that the four larger lobes do not represent individuals of a tetrad. If the spore is an eight-lobed individual, it is difficult to interpret its structure.

The spore is figured here, as it is the only spore of its kind found in the preparation. It might serve as an index spore for fixing the horizon of the plant bed.

Spore 9 (I, 1, c, i (1)).

Pl. 6, fig. 67

Spore approximately round; surface tuberculate, tubercles short; wall thin. Body  $56\mu$ .

There are some folds on the body which might have been brought about by the thinness of the body wall.

Spore 15, (I, 3, a, i (1)).

Pl. 6, fig. 68; Text-fig. 37.

Spore approximately round; triradiate slit clear; surface finely granular wall thin. Spore  $104.5\mu \times 102\mu$ .

Certain irregular folds seen on the surface of the body may either represent the rudiments of wings or be only accidental.

Spore 21, (I, 3, a, v (1)).

Pl. 6, fig. 69; Text-fig. 38.

Spore triangular; angles rounded; arms of the triradiate cavity long margin of the cavity thickened; surface smooth; wall thin. Axis  $62\mu$ .

The triradiate cavity might have been formed due to dehiscence.

Spore 22, (I, 3, b, i (1)).

Pl. 6 fig. 70.

Spore somewhat triangular; triradiate fold on the surface; surface wrinkled. Axis  $74\mu$ ; wall  $4\mu$ .

The triradiate fold appears to be quite definite; most probably, it represents the tetrad mark.

Spore 23 (1, 3, c, i, (1)).

Pl. 6, figs. 71-73; Text-fig. 39.

Spore 23 has been described on p. (Pl. 4, fig. 41.) Shape from angular (fig. 72) to round (figs. 71, 73); triradiate mark clear in fig. 72; surface faintly spinous.

Measurements are as follow:—

Fig.	Spore.
71	31 $\mu$ (individual).
72	30 $\mu$
73	28 $\mu$

Spores in figs. 72 and 73 are placed in the same 'species' as spores of intermediate shapes are observed. Spores of this type are generally seen adhering to the lower cuticle of certain species of *Glossopteris*.

The position of the spores in fig 71 is doubtful in this group, due to the abnormal way of grouping of the spores. Yet their shapes and structure are similar to the other spores, specially the one in fig 73. If the group of spores is a tetrad and if it really belongs to the same species as the other two, then it is not possible to account for the triradiate mark seen on the spore (fig. 72). Either the spores (fig 71) belong to another species or they are accidentally grouped together. Anyhow they are provisionally placed in the group *Spore 23*.

All these spores show a general resemblance to the smaller spore shown in Pl. 4, fig. 41, already described above as doubtfully belonging to *Alathopteris*.

Occurrence:—

20-25 ft. horizon, Kathwai, Pl. 4, fig. 41.

Spore 24 (1, 3, c, ii (1)).

Pl. 6, fig. 74; Text-fig. 40.

Spore triangular; angles rounded; arms of the triradiate slit nearly reaching to their respective angles; surface spinous, spines short, pointed and uniformly distributed; wall thin. Axis 64 $\mu$ .

This spore is quite different from *Spore 23* described above in its larger size, definite spines and long arms of the triradiate mark reaching to the angles.

Spore 25, (I, 3 d, i (1)).

Pl. 6, fig. 75; Text-fig. 41.

Spore round; triradiate mark extends to the margin of the spore; surface tuberculate, tubercles short, and arranged in somewhat concentric circles. Spore  $50\mu$ .

Spore 26, (I, 3, d, ii (1)).

Pl. 6, fig. 76.

Spore round; arms of the triangular cavity short, margins thickened surface tuberculate, tubercles comparatively stout and closely arranged Spore  $60\mu$ .

The thickening round the cavity, if not a definite character of the spore, might have been formed by the receding of the margins of the slit.

Spore 27, (I, 3, d, iii (1)).

Pl. 6, fig. 77; Text-fig. 42.

Spore triangular; arms of the triangular cavity rather long; margins thickened; surface tuberculate, tubercles comparatively long and uniformly distributed. Axis  $68\mu$ .

#### ONE-WINGED SPORES.

Spore 34, (II, i, b, iii (1)).

Pl. 6, fig. 78, 79; Text-fig. 43.

Spores broadly elliptical,  $157\mu$ - $168\mu$  long,  $112\mu$ - $118\mu$  broad; body broadly elliptical,  $85\mu$ - $92\mu$  long,  $75\mu$  broad, not well-preserved; wall thick, transverse axis of the wing longer than the vertical axis; coarsely granular.

Measurements are as follow:—

Fig.	Spore.	Body.	Rim.
78	$168\mu \times 118\mu$	$92\mu \times 75\mu$	$10\mu$
79	$157\mu \times 112\mu$	$85\mu \times 78\mu$	$8\mu$

Spore 40, (II, 2, b, i (1)).

Pl. 6, fig. 80; Text-fig. 44.

Spore 40 from the  $1\frac{1}{2}$  ft. horizon (Pl. 1, fig. 9; Text-fig. 15), has already been described The spore in fig. 80 is better preserved. The size is more or less the same as that of the one from the  $1\frac{1}{2}$  ft. horizon. The

body is very dark and the crescent-shaped slit (*sl.* in fig. 80 and Text-fig. 44) could only be faintly seen in the photograph; rim (*r*) is very thick. Spore  $121\mu \times 88\mu$ ; body  $62\mu \times 52\mu$ ; rim  $10\mu$ .

Occurrence:—

1½ ft. horizon, Kathwai, Pl. 1, fig. 9.

Spore 46, (II, 3, b, i (5)).

Pl. 6, fig. 81.

Spore round; body approximately round; triradiate mark (*sl.*) faint; rim thick; wing narrow,  $\frac{1}{4}$  to  $\frac{1}{2}$  the diameter of the body, radially striated. Spore  $118\mu$ ; body  $100\mu \times 92\mu$ ; rim  $9\mu$ .

The proportion of the wing to the body is the same as in *Spore 45* (Pl. 2, figs. 11, 12) but *Spore 46* is larger in size.

Spore 56, (II, 3, b, i (15)).

Pl. 6, fig. 82.

Spore broadly elliptical; body approximately round; triradiate mark not clear; rim thick; transverse axis of the wing nearly double its vertical axis ( $\frac{1}{2}$  the transverse diameter of the body), radially striated. Body  $56\mu \times 46\mu$ ; rim  $12\mu$ ; transverse axis  $23.2\mu$ ; vertical axis  $11\mu$ .

In this spore a tendency is noticed for the wing to get narrower above and below and broader on either side. This spore probably indicates a gradual change towards the two-winged type.

The spore from Warchha shows a general resemblance to *Spore 56* from the Pali beds, Rewa (Pl. 12; figs 151, 152) in its shape and structure, though not in size.

Occurrence:—

Pali beds, Rewa, Pl. 12; figs. 151, 152,

Spore 60, (II, 3, b, i (19)).

Pl. 6; fig. 83.

Spore elliptical, body round, triradiate mark faint (not clearly seen in the photograph), rim thick, vertical axis of the wing absent or nearly so. Body  $52\mu$ ; rim  $6\mu$ ; transverse axis of the wing  $20.5\mu$ .

This spore shows a step further towards the two-winged type. Although the spore is not quite two-winged the parts of the wing above and below the body (vertical axis) are insignificant.

The resemblance of this spore to the one in Pl. 12, fig. 154 from the Pali beds, Rewa, is striking though the latter is slightly larger and better preserved.

Occurrence:—

Pali beds, Rewa, Pl. 12, fig. 154.

#### TWO-WINGED SPORES.

Spore 64, (III, 1, *a*, iv (1)).

Pl. 6, fig. 84.

*Spore 64* of the 1½ ft. horizon already described above, Pl. 2, figs 17-19. Body 50μ; transverse axis of the wing 42.5μ; vertical axis 67μ. Even the size of the spore is not different from those already described especially those in Pl. 2. figs. 17 18.

Occurrence:—

1½ ft. horizon, Kathwai, Pl. 2, figs. 17-19.

20-25 ft. horizon, Kathwi, Pl. 5, fig. 35.

Spore 66, (III, I, *a*, v (1)).

Pl. 6, figs 85, 86.

Body round, dark; an outer broad transparent layer round the body; wings two, free parts rounded, radially striated, transverse and longitudinal axis more or less equal.

Measurements are as follow:—

Fig.	Body.	Transparent layer.	Transverse axis	Vertical axis.
85 . . .	32μ × 29μ	4μ	56μ	38.5μ
86 . . .	35μ × 34μ	4μ	48μ	48μ

The outer transparent layer round the margin of the dark central body; might represent the outer layer of the wall. In fig. 85 one wing is seen above the body. A thickening can be seen where the wing gets free from the body. This corresponds to the rim in the one-winged spores.

Spore 69 (III, 1, *a*, vi, (3)).

Pl 7, fig. 87; Text-fig. 45.

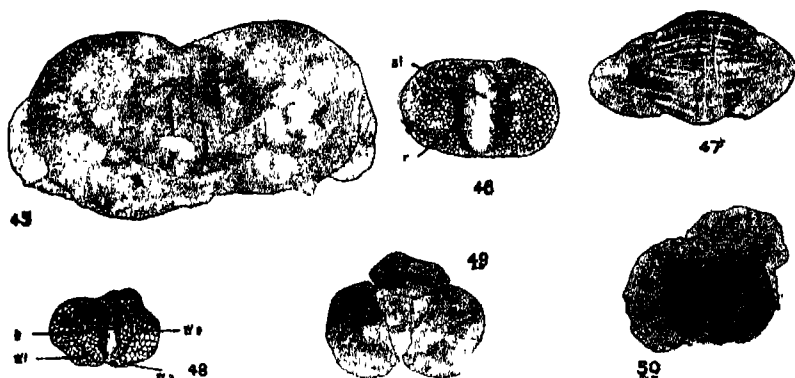
Body broadly elliptical; surface granulated; folds present; wings separate above, continuous below. Body 80μ × 66.4μ.

It is quite possible that one wing lies over the other so that both appear to be fused. The wing is much bigger than the body, but it is not possible to give the exact measurement as its inner margin is invisible.

In its shape and structure this spore can be compared with *Spore 69* from the Pali beds, Rewa. (Pl. 12, fig 157).

Occurrence:—

Pail beds, Rewa, Pl. 12, fig 157.



ext-figs. 45-50. Camera lucida drawings of some of the spores from shales just below the Middle Productus Limestone, Warchha, all  $\times 250$ . Fig. 45. *Spore 69*. wings are separate above and continuous below (Pl. VII, fig. 87). Fig. 46. *Spore 75*, *sl*-longitudinal slit; *r*-rim (Pl. VII, fig 89). Fig. 47. *Spore 79*, *Pityosporites* sp., body somewhat pointed at both ends; structure of the longitudinal folds not known (Pl. VII, fig 90). Fig. 48. *Spore 94*, *b*-spherical body; *wl-ws*-three wings (Pl. VII, fig. 97). Fig. 49. *Spore 96*, attachment of the wings intra-marginal (Pl. VII, fig. 98). Fig. 50. *Spore 97*, transverse and longitudinal stripes of the body are shown (Pl. VII, fig. 99).

#### CAYTONANTHUS-LIKE SPORES

Spore 74 (III, 2, a, i (1) ).

Pl. 7, fig. 88.

Body elliptical; slit longitudinal and fairly long (*sl*. in fig.88; rim (*r*) thick; wings finely pitted, pitting observed even on the surface of the body. Body  $40\mu \times 26\mu$ ; transverse axis  $16.5\mu$ ; vertical axis  $40\mu$ .

In its structure and shape this spore shows a striking resemblance to that of *Caytonanthus* sp. A, figured by Harris (1937, p. 44; Text-fig. 4. A) from the Rhaetic of Greenland, but our spore is about thrice as big as the Greenland spore.

Spore 75 (III, 2, a, i (2) ).

Pl. 7, fig. 89; Text-fig. 46.

Body elliptical; slit (Text-fig. 46, *sl* —also see fig. 89, *sl.*) longitudinal; rim (*r.*) thick; surface of the wing pitted, fine pitting extending over the body also, pits separated by ridges. Body  $47\mu \times 28\mu$ ; rim  $10\mu$ ; transverse axis of the wing  $27.5\mu$ ; vertical axis  $47\mu$ .

The similarity of the spore with *Caytonanthus arberi* Thomas (Harris 1937, pp. 44, 45; Text-fig. 4, E. G ) from the Rhaetic of Greenland is quite striking. The shape of the spore and body, the presence of the longitudinal slit and the nature of the pitting on the wings and body are alike in both the spores; but *Spore 75* is nearly double the size of *C. arberi*.

PITYOSPORITES Seward.

Spore 79 (III, 2, a, ii (3) ), *Pityosporites* sp.

Pl. 7, fig. 90; Text-fig. 47.

Body broad in the middle and somewhat pointed at the ends, transverse stripes clear; transverse axis of the wing  $\frac{1}{2}$  that of the body, radially striated. Body  $70\mu \times 60\mu$ ; transverse axis of the wing  $41\mu$ .

There are two longitudinal folds on the surface of the body. It is difficult to determine whether they represent a structural feature found in association with the slit

Spore 80 (III, 2, a, ii, (4) ), *Pityosporites* sp.

Pl. 7, fig. 91.

Body round; wall thick; transverse axis of the wing about  $\frac{3}{4}$  that of the body. Body  $69\mu$ ; wall  $4\mu$ ; transverse axis of the wing  $50\mu$

The spore presents its lateral view in which the thick dorsal wall of the body is also clearly seen.

The proportion of the wing to the body is greater in this spore than in *Spore 79*.

Spore 83 (III, 2, a, ii, (7) ), *Pityosporites* sp.

Pl. 7, fig. 92.

Body approximately round, transversely striped; transverse axis of the wing  $\frac{1}{2}$  that of the body. Body  $78\mu \times 74\mu$ ; transverse axis of the wing  $54\mu$ .

The proportion of the wing to the body is greater than in the previous case. It is therefore assigned to a different 'species'.

Occurrence:—

20-25 ft. horizon Kathwai; Pl. 5, fig. 28.

Pali beds, Rewa; Pl. 13, fig. 162.

Spore 85 (III, 2, a, ii, (9) ), *Pityosporites* sp.

Pl. 7, fig. 93.

Spore almost similar to *Spore 84* (*Pityosporites sewardi*) described above (Pl. 5, fig. 59) except in size. Body  $41\mu \times 29\mu$ ; transverse axis of the wing  $34\mu$ .

Occurrence:—

Daltongunj coalfield, Bihar; Pl. 8, fig. 123.

Pali beds, Rewa; Pl. 13, fig. 166.

Permo-Carboniferous shale, Newcastle Pl. 15, figs. 190 A.

Spore 87 (III, 2, a, ii, (11) ), *Pityosporites* sp.

Pl. 7, figs 94, 95.

*Spore 87* from the  $1\frac{1}{2}$  ft. horizon already described (Pl. 2, figs. 22, 23).

Fig. 94 represents the ventral and fig. 95 the lateral views. Measurements of the spore in fig. 95 are not given. Spore (fig. 94) — Body  $42\mu$ ; transverse axis of the wing  $48\mu$ .

Occurrence:—

$1\frac{1}{2}$  ft. horizon, Kathwai; Pl. 2, figs. 22, 23.

20-25 ft. horizon, Kathwai; Pl. 5, fig. 60.

Jhallelwari; Pl. 7, fig. 105.

Daltongunj coalfield, Bihar; Pl. I, figs. 4, 5.

Pali beds, Rewa; Pl. 13, figs. 168—172.

Spore 92 (III, 2, a, ii, (16) ), *Pityosporites* sp.

Pl. 7, fig. 96.

Body somewhat triangular, transversely striped; wall thick; transverse axis of the wing  $1\frac{1}{2}$  times that of the body. Body  $40\mu$  across at the broadest part; wall  $6\mu$ , transverse axis of the wing  $56\mu$ .

A clear median space is seen between the attachment of the wings. This space probably represents the part not covered by the wings; it is unlikely that it is a slit, as the latter is seldom seen in lateral view.



This spore is removed from *Spore 87* as the body is proportionately smaller than the wing.

THREE-WINGED SPORES.

Spore 94 (IV, 1, a, i, (1) ).

Pl. 7, fig. 97; Text-fig. 48

Body (fig. 97, b.; Text fig 48, b.) spherical; surface finely granulated; wings three ( $w^1$ ,  $w^2$ ,  $w^3$ ,) more or less uniform, attached to the body in one plane presumably at equal distance from each other, surface of the wing finely pitted. Body  $30.4\mu$ ; transverse axis of the wing  $27\mu$ .

Spore 96 (IV, 1, b, ii, (1) ).

Pl. 7, fig. 98; Text-fig. 49.

Spore flat; wall quite thick; wings three, sizes different, attachment of the wings intra-marginal. Body  $50\mu$ ; transverse axis of an average wing  $29\mu$ .

Spore 97 (IV, 1, b, iii, (1) ).

Pl. 7, fig. 99; Text-fig. 50.

Body oblong, dark, longitudinally and transversely striped (stripes shown in the text-fig., but not brought out in the photograph); wings three, attachment intra-marginal, radially striated. Body  $60\mu \times 48\mu$ ; transverse axis of the wing  $38\mu$ .

The text-figure shows only two wings as the third was broken off.

5. SPORES FROM JUST BELOW THE MIDDLE PRODUCTUS LIMESTONE,  
JHALLEWALI, SALT RANGE.

Pl. 7, figs. 100-105; Text-fig. 51.

The locality, horizon and material are already dealt with in another paper not yet published.

UNWINGED SPORES.

Spore 11 (1, 2, a, 1, (2) ).

Pl. 7, fig. 100.

Spore approximately round; longitudinal fold present; surface smooth; wall thick. Body  $74\mu \times 60\mu$ .

The longitudinal fold is also seen in two other spores referable to *Spore 11*. Most probably this fold is not accidental and may represent the germinal apparatus. The spore is, therefore, doubtfully placed in the group with the longitudinal slit.

Spore 20 (I, 3, a, iv, (1) ).

Pl. 7, fig. 101.

A description of *Spore 20* from the 20-25 ft. horizon is already given (Pl. 4, fig. 40) The present spore is slightly smaller than that in fig. 40. Besides, the knob is absent. In all other characters it resembles the spore previously described. Longest axis  $52\mu$ .

Occurrence:—

20-25 ft. horizon, Kathwai, Pl. 4, fig. 40.

#### ONE-WINGED SPORES.

Spore 31 (II, 1, b, i, (2) ).

Pl. 7, fig. 102.

*Spore 31* from the 20-25 ft. horizon has already been described (Pl. 4, figs. 42, 43) The spore in fig. 102 shows a more clearly-demarcated body than the rest of the spores under this group. Spore  $168\mu \times 123\mu$ . Body  $98\mu \times 84\mu$ .

Occurrence:—

20-25 ft. horizon, Kathwai; Pl. 4, fig. 42, 43.

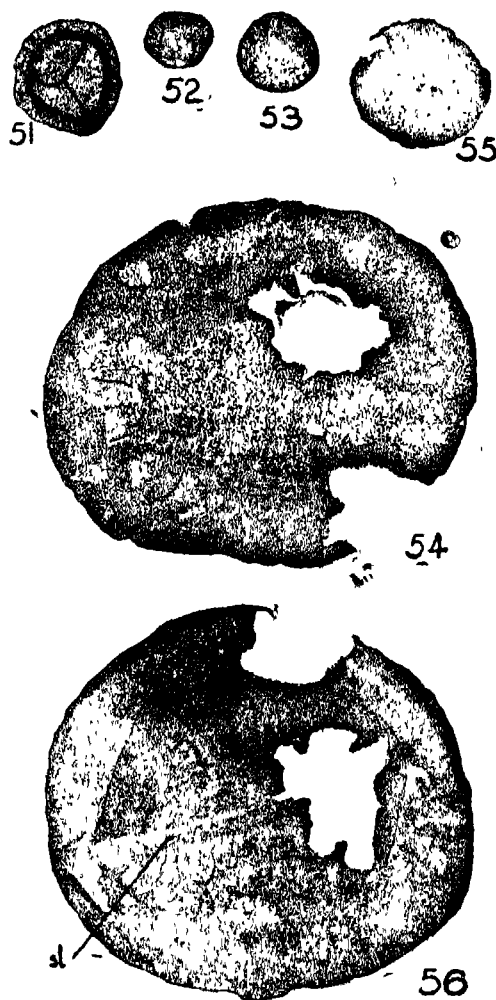
Spore 41 (II, 3, a, i, (1) )

Pl. 7 fig. 103; Text-fig. 51.

Spore roundly triangular; triradiate mark present, arms extend to the margin; wall thick; wing flat and narrow with radial folds. Axis of the body  $50\mu$ ; wall  $6\mu$ ; wing  $6\mu$  (broad).

The resemblance of this spore with that of *Selaginella parkei*, as figured by (Knox 1938, p. 443; fig. 23), is very striking, especially in its roundly angular outline, in the presence of the triradiate mark reaching the margin of the

body and in the narrow wings. Spores of *Selaginella* sp. range from 15 $\mu$  to 60 $\mu$ . No attempt is made here to draw any close comparison.



Text-fig. 51-Camera lucida drawing of *Spore 41* shown in Pl. VII. fig. 103. This spore belongs to the horizon just below the Middle Productus Limestone, Jhallerwali,  $\times 250$ .

Text-figs. 52-56. Camera lucida drawings of some of the spores from the Palibeds, Rewa, all  $\times 250$ . Fig. 52. *Spore 1* is also shown in Pl. X, fig. 128. Fig. 53. *Spore 2* is shown in Pl. X, fig. 129. Fig. 54. *Spore 4*, the upper layer of the body might have been torn off from the centre (Pl. X, fig. 130). Fig. 55. *Spore 7*, spinous surface (Pl. X, fig. 132). Fig. 56. *Spore 88*, sl.-slit (Pl. XI, fig. 137).

TWO-WINGED SPORES.

CAYTONANTHUS-LIKE SPORE.

Spore 76 (III, 2, a. i, (3) ).

Pl. 7, fig. 104.

Body approximately round; surface finely pitted; longitudinal slit distinct; attachment of the wings to the body clear, surface pitted.

This spore differs from *Spore 75* (Pl 7, fig. 89) in its larger size and the spherical shape of the body. The pitting on the surface of the body and the wing are not so regular as in *Spore 75*. Body  $67\mu \times 63\mu$ ; rim  $10\mu$ ; transverse axis of the wing  $32\mu$ .

PITYOSPORITES Seward.

Spore 87 (III, 2, a, ii, (11) ), *Pityosporites* sp.

Pl. 7, fig. 105.

*Spore 87* from the  $1\frac{1}{2}$  ft. horizon (Pl. 2, figs. 22, 23) has already been described. The photograph shows clearly the attachment of the wings to the body. Body  $52\mu \times 49\mu$ ; wall  $3\mu$ ; transverse axis of the wing  $47\mu$ .

Occurrence:—

$1\frac{1}{2}$  ft. horizon, Kathwai; Pl. 2, figs. 22, 23.

20-25 ft. horizon, Kathwai; Pl. 5, fig. 60.

Warchha; Pl. 7, figs. 94, 95.

Daltongunj coalfield, Bihar; Pl. 1, figs. 4, 5.

Pali beds, Rewa; Pl. 13, figs. 168-172; Text-fig. 72.

6. SPORES AND OTHER ORGANIC REMAINS FROM THE DALTONGUNJ COALFIELD, BIHAR.

Pl. 8.

The spores described here were obtained from a piece of shale bearing a well-preserved frond of *Glossopteris communis*. The leaf and its cuticle will be described in a future paper, the attribution of the adherent spores will there be briefly discussed, and the locality, horizon and the registered number of the specimen will also be given.

TRACHEID.

Pl. 8, fig. 106.

This piece of tracheid, with two series of bordered pits arranged alternately, shows a remarkable resemblance to that described from Warchha (p. 1 Pl. 6, fig. 62) in the round shape of the pits, their size and arrangement. It is not possible to suggest its affinity with any specific Palaeozoic wood.

UNWINGED SPORES.

Spore 3 (I, 1, a, ii, (1)).

Pl. 8; fig. 107.

Spore broadly elliptical; surface coarsely granular; wall thin. Spore  $146\mu \times 125\mu$ .

ONE-WINGED SPORES

Spore 28 (II, 1, a, i, (1)).

Pl. 8, fig. 108.

Spore broadly elliptical; body broadly elliptical, dark, surface granular; wing of uniform width all round (equatorial), nearly  $\frac{1}{2}$  the diameter of the body, surface coarsely granular. Spore  $77\mu \times 64\mu$ ; body  $48\mu \times 39\mu$ .

Spore 29 (II, 1, a, i, (2)).

Pl. 8, fig. 109.

Spore approximately round, one side not well-preserved; body approximately round; surface granular; wing more or less of uniform width, nearly half the diameter of the body, surface coarsely granular. Spore  $96\mu \times 92\mu$ ; body  $47\mu \times 42\mu$ .

The spore differs from Spore 28 in its size and proportion of the wing to the body.

Spore 43 (II, 3, b, i, (2)).

Pl. 8, figs. 110, 111.

Spores broadly elliptical; body broadly elliptical; triradiate slit not clear: rim thick; wing frill-like, radially striated

Measurements are as follow:—

Fig.	Spore.	Body.	Rim.
110	$76\mu \times 62\mu$	$54\mu \times 44\mu$	$8\mu$
111	$80\mu \times 62\mu$	$58\mu \times 46\mu$	$9\mu$

The spore in fig. 111 was obtained from the upper cuticle of *Glossopteris communis* shown in Pl. 18, fig. 142

Occurrence:—

Pali beds, Rewa; Pl. 11, fig. 141; Text-fig. 58.

Glacial tillite, Bacchus Marsh; Pl. 14, figs. 181-183.

Spore 44 (II, 3, b, i, (3)).

Pl. 8, fig. 112.

This spore resembles Spore 43 in its shape and structure, though not in size. The triradiate mark is not clear in the photograph. Spore  $114\mu \times 100\mu$ ; body  $79\mu \times 70\mu$ ; rim  $15\mu$ .

This spore has been figured in a previous communication, (*Virkki 1939, Pl. 1, fig. 11*).

Occurrence:—

Pali beds, Rewa; Pl. 11, fig. 142.

Spore 45 (II, 3, b, i, (4) ).

Pl. 8, figs. 113-115.

Spore 45 from the  $1\frac{1}{2}$  ft. horizon (Pl. 2, figs. 11, 12) and the  $4\frac{1}{2}$  ft. horizon (Pl. 3, fig. 27) already described. The triradiate slit is present in all the three. In fig. 115 it is partially hidden by the black patch of foreign matter.

Measurements are as follow:—

Fig.	Spore.	Body	Rim.
113	$94\mu \times 76\mu$	$69\mu \times 50\mu$	$8\mu$
114	$105\mu \times 94\mu$	$75\mu \times 65\mu$	...
115	$100\mu \times 88\mu$	$86\mu \times 78\mu$	...

Occurrence:—

$1\frac{1}{2}$  ft. horizon, Kathwai, Pl. 2, figs. 11, 12.

$4\frac{1}{2}$  ft. horizon, Kathwai, Pl. 3, fig. 27.

Spore 48 (II, 3, b, i, (7) ).

Pl. 8, fig. 116.

Spore 48 from the 20-25 ft. horizon (Pl. 4, fig. 45) already described. The spore is fairly well-preserved. Spore  $9\frac{1}{2}\mu \times 86\mu$ ; body  $61\mu$

This spore has been figured in a previous paper. (*Virkki 1939, Pl. 1, fig. 10*).

Occurrence:—

20-25 ft. horizon, Kathwai, Pl. 4, fig. 45.

Glacial tillite, Bacchus Marsh, Pl. 14, fig. 184.

Spore 49 (II, 3, b, i, (8) ).

Pl. 8, fig. 117.

Spore not well-preserved; triradiate mark not seen; rim thick. Spore  $29\mu \times 110\mu$ ; body  $90\mu \times 72\mu$ ; rim  $16\mu$ .

Occurrence:—

$1\frac{1}{2}$  ft. horizon, Kathwai, Pl. 2, fig. 14.

20-25 ft. horizon, Kathwai, Pl. 4, figs. 46, 47.

Pali beds, Rewa, Pl. 11. figs. 143-145.

Glacial tillite, Bacchus Marsh, Pl. 14, fig. 185.

# TWO-WINGED SPORES.

Spore 70 (III, 1, a, vii, (1) ).

Pl. 8, fig. 118.

Body approximately round dark; transverse axis  $1\frac{1}{2}$  times the diameter of the body; vertical axis thrice that of the body. Body  $33\mu \times 24\mu$ ; transverse axis of the wing  $58\mu$ ; vertical axis  $68\mu$ .

# PITYOSPORITES Seward.

Spore 77 (III, 2, a, ii, (1) ). *Pityosporites* sp.

Pl. 8, fig. 119.

Body broadly elliptical, transversely striped; transverse axis of the wing half the diameter of the body, radially striated. Body  $36\mu \times 32\mu$ ; transverse axis of the wing  $18\mu$ .

Spore 81 (III, 2, a, ii, (5) ). *Pityosporites* sp.

Pl. 8, figs. 120-122.

Body approximately round; diameter ranges from  $42\mu$ — $54\mu$ , stripes not seen; attachment of the wings quite clear, transverse axis of the wing  $\frac{1}{2}$  that of the body.

Measurements are as follow:—

Fig.	Body.	Transverse axis of the wing.
120	$42\mu \times 42\mu$	$27\mu$
121	$54\mu \times 48\mu$	$32\mu$
122	$52\mu \times 43\mu$	$39\mu$

To a certain extent in their shape and structure these spores resemble *Spore 82* (Pl. 13, figs. 160, 161) and *Spore 83* (Pl. 13, fig. 162) from the Pali beds of Rewa. The absence of stripes may be of specific importance or may have been brought about by bad preservation. *Spore 81* is smaller in size than *Spore 82* and *Spore 83*.

Spore 85 (III, 2, a, ii, (9) ), *Pityosporites* sp.

Pl. 13, fig. 123.

Spore 85 already described elsewhere (Pl. 7, fig. 93). Stripes very faintly seen. Body  $32\mu \times 30\mu$ ; transverse axis of the wing  $26\mu$ .

Occurrence:—

Warchha, Pl. 7, fig. 93.

Pali beds, Rewa, Pl. 13, fig. 166.

Permo-Carboniferous shale, Newcastle, Pl. 15, figs. 190, 193, 94.

Spore 87 (III, 2, a, ii, (11) ), *Pityosporites* sp.

Pl. 1, figs. 4, 5.

Fig. 4 represents the lower cuticle of *Glossopteris communis* with the spores adhering to it. One of them (*Pit.*) is further enlarged in fig. 5. This spore presents its lateral view.

Occurrence :—

$1\frac{1}{2}$  ft. horizon, Kathwai, Pl. 2 figs. 22, 23.

20-25 ft. horizon, Kathwai, Pl. 5, fig. 60.

Warchha, Pl. 7, figs. 94, 95.

Jhallelwari, Pl. 7, fig. 105.

Pali beds, Rewa, Pl. 13, figs. 168-172.

Spore 88 (III, 2, a, ii, (12) ), *Pityosporites* sp.

Pl. 8, fig. 124.

Body elliptical, transverse stripes not visible; longitudinal slit faintly seen. Body  $43\mu \times 33\mu$ ; wing (transverse axis)  $45\mu$ .

In shape and structure this spore resembles *Spore 89* from the Pali beds of Rewa (p. Pl. 13, fig. 173); but due to the difference in size and absence of stripes on the body, the spore from Bihar is placed in a different 'species'.

## 7. SPORES AND OTHER ORGANIC REMAINS FROM THE PALI BEDS, REWA

Pls. 8-13; Text-figs. 52-76.

The discovery of spores in the shales from the Salt Range led to the examination of similar shales from other localities in India. Of several pieces of shales from Rewa (carrying impressions of *Glossopteris* sp.) handed over to me by Professor Sahni, all except one were red shales and they did not



yield any organic remains on maceration. The one dark shale yielded a considerable variety of spores, bits of tracheids and cuticles with stomata. ~

*Locality and horizon.*—The locality lies at the junction of the Ganjra nala with the Johilla river about two miles west of Pali in Central India (23° 22' N ; 80° 4' E.). The specimen bore the registered number K25/523 of the Geological Survey of India.

The horizon and age of the plant beds in South Rewa had been a puzzle for the past many years. It was thought that the plant-beds at Parsora containing well-preserved specimens of *Thinnfeldia*, and those at Daigon and Pali (Southern part), which contained members of the *Glossopteris* flora, were of the same series. Dr. C S Fox (1931, pp. 172, 173, 183-190) suggests that the Daigon-Pali beds have plant remains of the Damuda facies and the Parsora beds contain a flora allied to the Rajmahal (Upper Gondwana) group. The fossil in question belongs to the Pali beds, which are now regarded as belonging to the Kamthi or Ranigunj series (Upper Permian) (Wadia 1938, p. 95).

*Material.*—The carbonaceous shale from which spores were obtained is represented in Pl. 9, fig. 125. The material for maceration was removed from the upper part of the specimen, from a place indicated by the arrow mark. The nature of the shale is such that it easily gets disintegrated in water. The spores obtained were numerous and well-preserved. Groups of spores of the *Pityosporites* type were very common.

#### STOMA.

##### Pl. 9, fig. 126.

Pl. 9, fig. 126 represents a single isolated stoma obtained along with the spores. The guard cells and the stomatal pore are not preserved; the six subsidiary cells, each with an overhanging papilla, are prominent.

It may not be advisable to suggest a comparison of this stoma with those already described, as we are in the dark regarding the other part of the cuticle. Yet it can be mentioned here that the stoma in fig. 126 shows a resemblance to that of *Glossopteris browniana*, in the number and nature of the subsidiary cells, though not in size. Comparison can also be drawn with the stoma of *Glossopteris communis* in its size and in the structure of the subsidiary cells. No attempt is made here to draw any definite conclusion.

# TRACHEIDS.

Pl. 9, fig 127.

The tracheids represented in fig. 127 are well-preserved.

The pits are round to hexagonal and are either opposite or alternate. The pores are round to elliptical. Besides these, there are a few cells of the medullary rays also.

These bits of tracheids show a resemblance to those from Warchha (Pl. 6 fig. 62) and Daltongunj coalfield, Bihar (Pl. 8, fig. 106).

# UNWINGED SPORES.

Spore 1 (I, 1, a, i, (1)).

Pl. 10, fig. 128; Text-fig. 52.

Spore elliptical; folds on the surface; surface smooth; wall thin. Spore  $38\mu \times 28\mu$ .

Spore 1 from the  $1\frac{1}{2}$  ft. horizon (Pl. 1, fig. 3) and the  $4\frac{1}{2}$  ft. horizon (Pl. 3, fig. 24) already described. The spore in fig. 128 is slightly different in shape, probably due to the presence of folds on the surface.

Occurrence :—

$1\frac{1}{2}$  ft. horizon, Kathwai, Pl. 1, fig. 3.

$4\frac{1}{2}$  ft. horizon, Kathwai, Pl. 3, fig. 24.

Glacial tillite, Bacchus Marsh, Pl. 14, fig. 178.

Spore 2 (I, 1, a, i, (2)).

Pl. 10, fig. 129; Text-fig. 53.

Spore roundly triangular; surface smooth; wall thick. Axis  $43\mu$ ; wall  $2\mu$ .

Spore 4 (I, 1, a, ii, (2)).

Pl. 10, figs. 130, 131; Text-fig. 54.

Spore elliptical,  $230\mu$  to  $252\mu$  long,  $194\mu$  to  $201\mu$  broad; surface coarsely granular; wall thin.

Measurements are as follow :—

Fig.	Body.
130	$230\mu \times 194\mu$
131	$252\mu \times 201\mu$

Spore 7 (I, 1, b, ii (1)).

Pl. 10, fig. 132; Text-fig. 55.

Spore approximately round: surface spinous, spines comparatively long and pointed, uniformly distributed; wall thin. Spore  $73\mu \times 68\mu$ .

Spore 8 (I, 1, b, i, (2)).

Pl. 10, fig. 133.

Spore triangular; surface spinous, spines long and pointed. As the spore cannot be traced its measurements are not given.

#### ONE-WINGED SPORES.

Spore 37 (II, 2, a, i, (1)).

Pl. 10, fig. 134.

Spore and body elliptical; slit long and broad; wing  $\frac{1}{5}$  to  $\frac{1}{6}$  the diameter of the body, surface coarsely granular. Spore  $184\mu \times 130\mu$ ; body  $136\mu \times 106\mu$ .

Spore 38 (II, 2, a, i, (2)).

Pl. 10, figs. 135, 136; Pl. 11, figs. 137, 138; Text-fig. 56.

Spores same as above, except in that Spore 38 is larger in size with a narrower slit (fig. 137 *sl*, Text-fig. 56, *sl*).

Measurements are as follow:—

Fig.	Spore.	Body.
136	$230\mu \times 176\mu$	$162\mu \times 124\mu$
137	$235\mu \times 223\mu$	$160\mu \times 142\mu$
138	$270\mu \times 220\mu$	$207\mu \times 130\mu$
286	not traceable.	

Spore 39 (II, 2, a, i, (3)).

Pl. 11, fig. 139.

Spore elliptical, but one of the sides straightened (probably due to the mode of preservation); body elliptical; fold faintly seen; wing  $\frac{1}{3}$  the diameter of the body, surface coarsely granular. Spore  $227\mu \times 160\mu$ ; body  $144\mu \times 96\mu$ .

This resembles Spore 38, except in the proportion of the wing to the body.

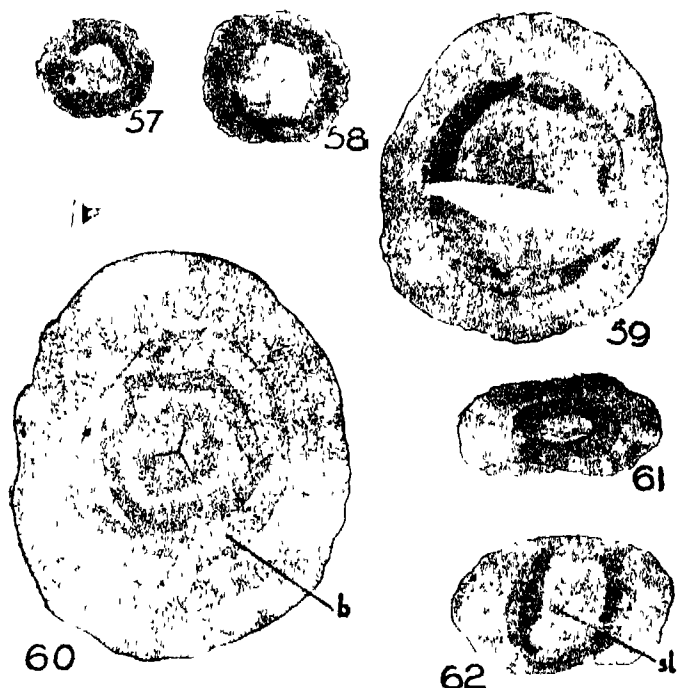
Spore 42 (II, 3, b, i, (1)).

Pl. 11, fig. 140; Text-fig. 57.

Spore 42 from the  $1\frac{1}{2}$  ft. horizon (Pl. 2, fig 10), has already been described. The spore in fig. 140 is more round with a clear triradiate mark. Spore  $56\mu \times 49\mu$ ; body  $44\mu$ ; rim  $8\mu$ .

Occurrence :—

. 1½ ft. horizon, Kathwai; Pl. 2, fig. 10.



Text-figs 57-62. Camera lucida drawings of some spores from the Pali beds, Rewa, all  $\times 250$ . Fig. 57. *Spore 42*, shown in Pl XI, fig. 140. Fig. 58. *Spore 43*, represented in Pl. XI, fig. 141. Fig. 59. *Spore 51*, the clear space shown in the figure is the region where there was a dirt particle (Pl XII, fig. 147). Fig. 60. *Spore 55*, *b*-body (Pl XII, fig. 150). Fig. 61. *Spore 57*, transverse fold on the body is accidental (Pl. XII, fig. 153). Fig. 62. *Spore 60*, *sl.*-triradiate slit (Pl. XII, fig. 154).

Spore 43 (II, 3, *b*, *i*, (2) ).

Pl. 11, fig. 141; Text-fig. 58.

*Spore 43* from the Daltongunj coalfield, Bihar (Pl. 8, figs. 110, 111) has already been described. Spore  $74\mu \times 68\mu$  ; body  $54\mu \times 51\mu$  ; rim  $8\mu$ .

The triradiate slit is clear.

Occurrence :—

Daltongunj coalfield, Bihar, Pl. 8, figs. 110, 111.

Glacial tillite, Bacchus Marsh, Pl 14, figs. 181, 183.

Spore 44, (II, 3, b, i, (3) ).

Pl. 11, fig. 142.

*Spore 44* from the Daltongunj coalfield, Bihar (Pl. 8, fig. 112) has already been described. Fig. 142 resembles fig. 111 in its size and shape. The triradiate slit is clear in the Rewa spore. Spore  $91\mu$ ; body  $78\mu \times 68\mu$ ; rim  $9\mu$ .

Occurrence :—

Daltongunj coalfield, Bihar, Pl. 8, fig. 112.

Spore 49 (II, 3, b, i, (8) ).

Pl. 11, figs. 143-145.

*Spore 49* from the  $1\frac{1}{2}$  ft. horizon (Pl. 2, fig. 14) has already been described.

In figs. 144, 145 the rim is seen as two folds ; probably the outer one represents the margin of the body or the rim on one side might have been slipped. The triradiate slits are not seen in these spores.

Measurements are as follow :—

Fig.	Spore.	Body.	Rim.
143	$106\mu$	$74\mu$	$10\mu$
144	$112\mu \times 108\mu$	$76\mu$	$9\mu$
145	$118\mu$	$87\mu$	$11\mu$

Occurrence :—

$1\frac{1}{2}$  ft. horizon, Kathwai, Pl. 2, fig. 14.

20-25 ft. horizon, Kathwai, Pl. 3, figs. 46, 47.

Daltongunj coalfield, Bihar, Pl. 8, fig. 117.

Glacial tillite, Bacchus Marsh, Pl. 14, fig. 185.

Spore 50 (II, 3, b, i, (9) ).

Pl. 11, fig. 146.

Spore and body elliptical; triradiate slit clear; rim thick; wing flat, radially striated. Spore  $140\mu \times 120\mu$ ; body  $100\mu \times 75\mu$ ; rim  $12\mu$ .

On the left hand side the rim is seen as two layers, the outer one of which probably represents the margin of the body. This spore resembles *Spore 50* represented in Pl. 14, fig. 185 (Bacchus Marsh), in its size and shape.

Occurrence:—

Glacial tillite, Bacchus Marsh; Pl. 14, fig. 186.

Spore 51 (II, 3, b, i, (10) ).

Pl. 12, fig. 147; Text-fig. 59.

*Spore 51* from the  $1\frac{1}{2}$  ft. horizon, Kathwai (Pl 2, fig. 15) already described. The spore in fig. 147 is better preserved.

Spore broadly elliptical; body approximately round; triradiate slit clear. Spore  $170\mu \times 150\mu$ ; body  $116\mu \times 104\mu$ ; rim  $14\mu$ .

Occurrence:—

$1\frac{1}{2}$  ft horizon, Kathwai, Pl. 2 fig. 15.

20-25 ft. horizon, Kathwai, Pl. 4, fig. 48.

Spore 53 (II, 3, b, i, (12) ).

Pl. 12, figs. 148, 149.

*Spore 53* from the 20-25 ft. horizon, Kathwai (Pl. 5; figs. 50, 51) has already been described. The spores in figs. 148, 149 are better preserved and the triradiate mark can be seen in both. Fig. 148 does not have a rim, but the radial striations of the wing are seen to continue even beyond the margin of the body. This evidently shows that the rim seen in several spores is in some way associated with the origin of the wing and does not seem to represent the thick body wall.

Measurements are as follow:

Fig.	Spore.	Body.	Rim.
148	$92\mu \times 82\mu$	$55\mu$	..
149	$88\mu \times 92\mu$	$50\mu$	$8\mu$

Occurrence:—

20-25 ft. horizon, Kathwai; Pl. 5; figs. 50, 51.

Spore 55 (II, 3, b, i, (14) ).

Pl. 12, fig. 150; Text-fig. 60.

Spore and body (fig. 150, b; Text-fig. 60, b) broadly elliptical; triradiate mark clear; rim irregular; wing more than half the diameter of the body; radially striated. Spore  $228\mu \times 176\mu$ ; body  $117\mu \times 109\mu$ .

A fold is seen on the body from where the striations of the wing are seen to start.

This spore is removed from *Spore 53* and *Spore 54* on account of its larger size.

Spore 56 (II, 3, b, i, (15) ).

Pl 12, figs. 151, 152.

*Spore 56* has already been described from Warchha (Pl. 6, fig. 82). The spores described here are better preserved and smaller than that shown in fig. 82. The triradiate mark is seen in both.

Measurements are as follow:—

Fig.	#	Body.	Rim	Transverse axis.	Vertical axis.
151	...	$8\mu \times 42\mu$	$7\mu$	$17\mu$	$6\mu$

As the spore shown in fig 303 cannot be traced, its measurements are not given.

These spores show an approach towards the two-winged type; for the transverse axis of the wing is longer than the vertical axis.

Occurrence:—

Warchha, Pl. 6, fig. 82.

Spore 57 (II, 3, b, i, (16) )

Pl 12, fig. 153; Text-fig. 61.

Spore somewhat similar to those grouped under *Spore 56*. Triradiate mark not visible; transverse axis of the wing nearly half and vertical axis less than 1/7 the diameter of the body. Body  $59\mu \times 37\mu$ ; rim  $9\mu$ , transverse axis of the wing  $25.5\mu$ ; vertical axis  $7.5\mu$ .

The transverse fold in the centre of the body is probably accidental, as another spore of the same size and shape does not show such a structure.

Spore 60 (II, 3, b, i, (19) ).

Pl. 12, fig. 154; Text-fig. 62.

*Spore 60* from Warchha (Pl. 6, fig. 83) has already been described. Spore elliptical; body approximately round; triradiate mark faintly seen (fig. 154 *sl.* ; Text-fig. 62 *sl.*).

The attachment of the wings on either side appears to be intra-marginal. The portions of the wing above and below, as seen in the figure, are extremely narrow. Body  $68\mu \times 59\mu$ , transverse axis of the wing  $20\mu$ ; vertical axis  $3\mu$ . This spore shows a greater approach towards the two-winged type.

Occurrence:—

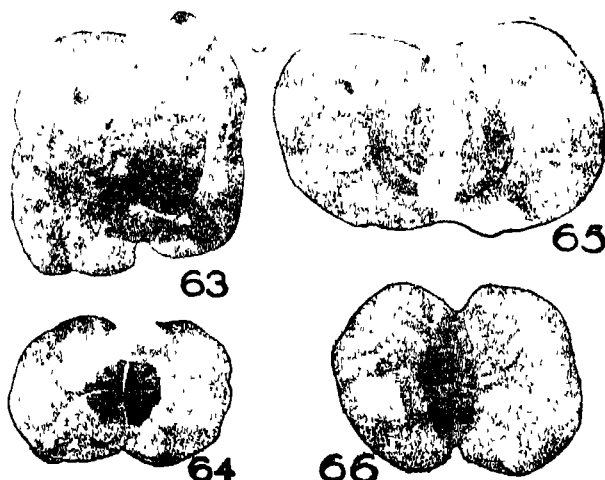
Warchha; Pl. 6, fig. 83.

TWO-WINGED SPORES.

Spore 63 (III, 1, a, iii, (1) ).

Pl. 12, fig. 155; Text-fig. 63.

Body approximately round, dark; wings two, transverse axis  $\frac{1}{2}$  and vertical axis  $1\frac{1}{2}$  times that of the body. Body  $88\mu \times 80\mu$ ; transverse axis  $58\mu$ ; vertical axis  $120\mu$ .



Text-figs. 63-66. Camera lucida drawing of some of the spores from the Pali beds, Rewa, all  $\times 250$ . Fig. 63. *Spore 63*, the drawing is not true to the photograph owing to the change in position of the 'spore'. (Pl. XII, fig. 155). Fig. 64. *Spore 68*, shown in Pl. XII, fig. 156. Fig. 65. *Spore 69*, also represented in Pl. XII, fig. 157. Fig. 66. *Spore 72*, shown in Pl. XII, fig. 158.

Spore 68 (III, 1, a, vi, (2) ).

Pl. 12, fig. 156; Text-fig. 64.

This spore has already been described above (20-25 ft. horizon). Although the size of the wings is the same in both, the spore described here has a slightly rounded body. Body  $34\mu$ ; transverse axis of the wing  $56\mu$ ; vertical axis  $74\mu$ .

Occurrence:—

20-25 ft. horizon, Kathwai, Pl. 5, fig. 57.

Spore 69 (III, 1, a, vi, (3) ).

Pl. 12, fig. 157; Text-fig. 65

*Spore 69* has already been described (Pl 7, fig. 87). As in the photograph the differentiation of the two wings can be seen above; but below they are continuous. Body  $67\mu$ ; wing  $99.5 \times 70\mu$  (approximate measurement).



Occurrence:—

Warchha; Pl. 7, fig. 87.

Spore 72 (III, 1, b, ii, (1) ).

Pl. 12, fig. 158; Text-fig. 66.

Body narrowly elliptical; wing attached parallel to the longer axis of the body. Body  $58\mu \times 26\mu$ ; transverse axis of the wing  $63\mu$ .

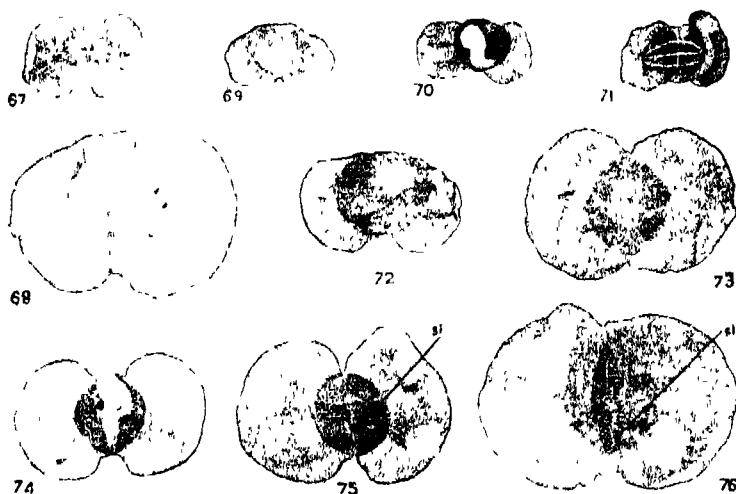
PITYOSPORITES Seward.

Spore 78 (III, 2, a, ii, (2) ). *Pityosporites* sp.

Pl. 13, fig. 159; Text-fig. 67.

Body elliptical, transversely striped; transverse axis of the wing  $\frac{1}{2}$  that of the body. Body  $50\mu \times 32\mu$ ; transverse axis of the wing  $26\mu$ .

This spore resembles *Spore 79* from Warchha (Pl. 7; fig. 90) especially in the size of the wing (proportion of the wing to the body). The smaller size of the Rewa specimen has necessitated its removal to another species.



Text-figs. 67-76. Camera lucida drawings of some spores from the Pali beds, Rewa, all  $\times 250$ . Fig. 67. *Spore 78*, *Pityosporites* sp. (Pl. XIII, fig. 159). Fig. 68. *Spore 83*, *Pityosporites* sp. (Pl. XIII, fig. 162). Figs. 69-71. *Spore 84*, *Pityosporites sewardi* represented in Pl. XIII, figs. 163-165. Fig. 72. *Spore 87*, *Pityosporites* sp., transverse stripes are shown (Pl. XIII, fig. 170). Fig. 73. *Spore 89*, *Pityosporites* sp., wings are pitted (Pl. XIII, fig. 173). Fig. 74. *Spore 90*, sp., sl. longitudinal slit, represented in Pl. XIII, fig. 174. Fig. 75. *Spore 91*, *Pityosporites* sp. (Pl. XIII, fig. 175). Fig. 76. *Spore 93*, sl.-slit with thickened margin (Pl. XIII, fig. 176).

Spore 82 (III, 2, a, ii, (6) ), *Pityosporites* sp.

Pl. 13, figs. 160, 161.

Body round, transversely striped (fig. 160).

The spore in fig. 161 has no stripes preserved; but it resembles the spore represented in fig. 160 in every other respect.

Measurements are as follow:—

Fig.	Body.	Transverse axis of the wing.
160 ...	58 $\mu$	41 $\mu$
161 ...	67 $\mu$	44 $\mu$

These spores are somewhat similar to *Spore 81* from Bihar (Pl. 8, figs 120-122) in their shape and structure, although in size they are larger.

Spore 83 (III, 2, a, ii, (7) ), *Pityosporites* sp.

Pl. 13, fig. 162; Text-fig. 68.

*Spore 83* from the 20-25 ft. horizon (Pl. 5, fig. 58; Text-fig. 34) and Warchha (Pl. 7. fig. 92) has already been described. Body 74 $\mu$   $\times$  59 $\mu$ ; transverse axis of the wing 52 $\mu$ .

Occurrence:—

20-25 ft. horizon, Kathwai, Pl. 5, fig. 58.

Warchha, Pl. 7, fig. 92.

Spore 84 (III, 2, a, ii, (8) ), *Pityosporites sewardi*.

Pl. 13, figs. 163-165; Text-figs. 69-71.

The spores referred to this species have been described elsewhere (Pl 5, fig. 59). The spores in figs. 163 , 164 present the lateral and in fig. 165 the ventral views.

Measurements are as follow:—

Fig.	Body.	Body wall.	Transverse axis of the wing.
163	...28 $\mu$ $\times$ 27 $\mu$	1 $\mu$	25 $\mu$
164	...28 $\mu$ $\times$ 26 $\mu$	2 $\mu$	27 $\mu$
165	...28 $\mu$ $\times$ 28 $\mu$	...	23 $\mu$

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Occurrence:—

20-25 ft. horizon Kathwai, Pl. 5, fig. 59.

Permo-Carboniferous shale, Newcastle, Pl. 15, figs. 190 B, 191, 192.

Spore 85 (III, 2, a, ii, (9) ), *Pityosporites* sp.

Pl. 13, fig. 166.

Spore 85 from Warchha (Pl. 7, fig. 93) has already been described. Slit is clearly visible. Body  $32\mu$ ; transverse axis of the wing  $84\mu$ .

Occurrence:—

Warchha, Pl. 7, fig. 93

Daltongunj coalfield, Bihar, Pl. 8, fig. 123.

Permo-Carboniferous shale, Newcastle, Pl. 15, figs. 190 A, 193, 194.

Spore 86 (III, 2, a, ii, (10) ), *Pityosporites* sp.

Pl. 13, fig. 167.

Spore 86 from the  $1\frac{1}{2}$  ft. horizon has already been described above Pl. 2, fig. 21. As the spore cannot be traced its measurements are not given.

Occurrence :—

$1\frac{1}{2}$  ft. horizon Kathwai, Pl. 2, fig. 21.

Spore 87 (III, 2, a, in, (11) ), *Pityosporites* sp.

Pl. 13, figs. 168-172 ; Text-fig. 72.

Spore 87 needs no more description, as the spores referable to this species have been described in all the previous sections except the one of the  $4\frac{1}{2}$  ft. horizon.

The spore in fig. 172 is an enlargement of *Pit.* from the group of spores shown in fig. 171. Such groups of spores are very common in the preparation.

Measurements of the spores are as follow :—

Fig.	Body.	Body wall.	Transverse axis of the wing.
158	... $41\mu \times 41\mu$	$3\mu$	$42\mu$
170	... $54\mu \times 44\mu$	...	$36\mu$
172	... $62\mu \times 44\mu$	, ...	$44\mu$

Occurrence :—

1½ ft. horizon, Kathwai, Pl. 2, figs. 22, 23.

20-25 ft. horizon, Kathwai, Pl. 5, fig. 60.

Warchha, Pl. 7, figs. 94, 95.

Jhallelwari, Pl. 7, fig. 105.

Daltongunj coalfield, Bihar; Pl. 1, figs. 4, 5.

Spore 89 (III, 2, a, ii, (13) ), *Pityosporites* sp.

Pl. 13, fig. 173; Text-fig. 73.

Spore elliptical, transversely striped; slit not visible, transverse axis of the wing 1½ times that of the body, granulation of the wing showing a tendency to be pitted (both the wings appear to be fused). Body  $50\mu \times 42\mu$ ; transverse axis of the wing  $55\mu$ .

Spore 90 (III, 2, a, ii, (14) ), *Pityosporites* sp.

Pl. 13, fig. 174; Text-fig. 74.

Body approximately round, transversely striped; slit faintly visible, transverse axis of the wing 1½ times that of the body. Body  $43\mu \times 38\mu$ ; transverse axis of the wing  $47\mu$ .

Spore 91 (III, 3, a, ii, (15) ), *Pityosporites* sp.

Pl. 13, fig. 175; Text-fig. 75.

Body round, transversely striped, slit faintly seen (fig. 175 and Text-fig. 75, *sl.*), transverse axis of the wing 1½ times that of the body. Body  $44\mu \times 40\mu$ . transverse axis of the wing  $60\mu$ .

Spore 93 (III, 3, b, i, (1) ).

Pl. 13, fig. 176; Text-fig. 76.

Body broadly elliptical, longitudinal slit extending to the wall (fig. 176 and Text-fig. 76 *sl.*) margins thickened, wings considerably larger than the body. Body  $60\mu \times 48\mu$ ; wing  $87\mu \times 66\mu$ .

## 8. SPORES AND OTHER ORGANIC REMAINS FROM THE GLACIAL TILLITE.

BACCHUS MARSH, VICTORIA.

Pl. 14.

As anticipated, the Permo-Carboniferous glacial tillite from Bacchus Marsh yielded on maceration various kinds of spores and organic remains. The fact that the shales only 1½ ft. above the Talchir Boulder bed in the Salt Range had yielded spores gave hopes of finding them even in the glacial matrix itself. So the work in this line was started, and at the request of Professor Sahni samples of the glacial matrix were supplied from many

localities in Australia. Samples were received only from one locality in Africa. Mr. Wadia of the Geological Survey of India supplied us with samples from Kashmir. The authorities of the British Museum were kind enough to send small pieces of tillites from Bacchus Marsh in Victoria (Australia) and from Cape Colony in Africa. A cursory examination of some of these materials was carried out; except the sample from Bacchus Marsh none else yielded spores. Incidentally it may be mentioned here that this locality is well known; for, *Gangamopteris* and *Schizoneura* were found in beds interstratified with the glacials (*Sussmilch, 1922, p. 144*). The discovery of spores from that locality is, therefore, not an unexpected one. It is of interest to note that most of the types of spores from Bacchus Marsh were strikingly similar to some of the spores from India, from horizons much higher than that of the Boulder bed. Similar spores were figured and briefly described in a previous communication (*Virkki, 1939, pp. 7-12; Pl. 1, figs. 1-5; Text-figs. a-d.*); such spores as have already been described are marked\*.

*Locality and horizon*—The piece of tillite, sent by the authorities of the British Museum, carried the following label "Tillite (Permo-Carboniferous), Coimadai Creek, Bacchus Marsh, Victoria, off B. N. 1925, 965."<sup>1</sup>

*Material.*—The tillite was slightly clayish with minute pebbles in it. It could be easily dissolved in Schulze's maceration fluid.

#### TRACHEID.

Pl. 14, fig. 177.

One of the small bits of tracheids obtained from the glacial tillite of Bacchus Marsh is represented in fig. 177. The pits on the tracheidal walls are only in one series. They are oval in shape and slightly larger than those already figured from Warchha (Pl. 6, fig. 62), Bihar (Pl. 8, fig. 106) and Rewa (Pl. 9, fig. 127). Besides, as said above, this has only one series of pits, while those already described have two to four such series.

#### UNWINGED SPORES.

Spore 1 (I, 1, a, i, (1) )

Pl. 14, fig. 178.

*Spore 1* from the 1½ ft. horizon (Pl. 1, fig. 3), 4½ ft. horizon (Pl. 3, fig. 24) and Pali beds (Pl. 10, fig. 128) already described. On the left hand side of the figure there is a fold which appears as a thick wall. Spore 38µ × 32µ.

<sup>1</sup>—In a letter, dated 2nd August, 1944, Professor E. S. Hills of Melbourne informs me that this glacial horizon is now regarded by Australian geologists as definitely Permian. B. Sahni.

**Occurrence:—**

1½ ft. horizon, Kathwai, Pl. 1, fig. 3.

4½ ft. horizon, Kathwai, Pl. 3, fig. 24.

Pali beds, Rewa, Pl. 10, fig. 128.

Spore 14 (I, 2, c, i, (1) ).

Pl. 14, fig. 179.

Spore somewhat elliptical, one end slightly broader than the other; slit as long as the body, sides thickened; surface faintly granular; wall thin. Spore  $56\mu \times 38\mu$ .

**ONE-WINGED SPORES.**

Spore 33 (II, 1, b, ii, (1) ).

(Pl. 14, fig. 180)

Spore and body elliptical; wall of the body thin with folds; trasverse axis of the wing broader than the vertical axis, granulation coarse. Spore  $146\mu \times 69\mu$ ; body  $101\mu \times 59\mu$ .

The wing near the centre of the spore is slightly ruptured, giving it an appearance of two wings.

Spore 43 (II, 3, b, i, (2) ).

Pl. 14, figs. 181, \*182, \*183.

Spore 43 has already been described above (Bihar) and (Rewa). The triradiate marks is preserved in all the three, although only in fig. 181 it is visible.

Measurements are as follow:—

Fig.	Spore.	Body.	Rim.
181	$74\mu \times 53\mu$	$48\mu \times 36\mu$	$9\mu$
182	$74\mu \times 63\mu$	$49\mu \times 45\mu$	$8\mu$
183	$86\mu \times 72\mu$	$53\mu \times 47\mu$	$7\mu$

**Occurrence:—**

Daltongunj coalfield, Bihar, Pl. 8, figs. 110, 111.

Pali beds, Rewa, Pl. 11, fig. 141.

Spore 48 (II, 3, b, i, (7) )

Pl. 14, fig. \*184.

Spore 48 from the 20-25 ft. horizon, (Pl. 4, fig. 45 ) and Daltongunj coalfield, Bihar, (Pl. 8, fig. 116) already dealt with. The two arms of the

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triradiate mark are clear in the photograph. Spore  $96\mu \times 87\mu$ ;  $72\mu \times 63\mu$ ; rim  $13\mu$ .

Occurrence:—

20-25 ft. horizon, Kathwai, Pl. 4, 45.

Daltongunj coalfield, Bihar, Pl. 8, 116.

Spore 49 (II, 3, b, i, (8) ).

Pl. 14, fig. \*185.

*Spore 49* needs no more description as it has been described above.

The triradiate mark is faintly seen in the photograph. A part of the spore is torn off. Spore  $118\mu \times 109\mu$ ; body  $83\mu \times 68\mu$ , rim  $12\mu$ .

Occurrence:—

1½ ft. horizon, Kathwai, Pl. 2, fig. 14.

20-25 ft. horizon, Kathwai, Pl. 4, figs. 46, 47.

Daltongunj coalfield, Bihar, Pl. 8, fig. 117.

Pali beds, Rewa, Pl. 11, figs. 143-145.

Spore 50 (II, 3, b, i, (9) ).

Pl. 14, fig. \*186.

*Spore 50* from the Pali beds, Rewa, has been described above (Pl. 11, fig. 146). The triradiate mark is quite faint in the photograph. Spore  $150\mu \times 114\mu$ ; body  $108\mu \times 72\mu$ ; rim  $14\mu$ .

Occurrence:—

Pali beds, Rewa, Pl. 14, fig. 146.

Spore 59 (II, 3, b, i, (18) ).

Pl. 15, fig. 187.

Spore elliptical, body approximately round, attachment of the wing intramarginal, triradiate mark not visible, transverse axis of the wing much greater than its vertical axis. Spore  $197\mu \times 126\mu$ ; body  $106\mu \times 94\mu$ .

Although the wing is actually single, the attachment of the wing to the body shows that there is a tendency for the wing to become double. Points of constriction are seen above and below. A part of the upper layer of the wing is torn away above, clearly displaying the lower layer.

This spore can be compared with *Spore 60* from Warchha, (Pl. 6, fig. 83) and Rewa, (Pl. 12, fig. 154); but the spores from these localities have their wings slightly more reduced both above and below the body.

#### ANIMAL REMAINS

##### Pl. 14, fig. 188.

The piece of chitin shown in fig. 188 was obtained along with the spores and bits of tracheids during maceration of the tillite. The top part of the photograph convinces us that it has the shape of a sheath. It has reticulate markings on the surface, and here and there pointed spines also are seen.

It is difficult to attribute this structure to any particular part of an animal; probably, it is part of the antenna of some insect.

#### 9. SPORES FROM THE PERMO-CARBONIFEROUS OF NEWCASTLE, NEW SOUTH WALES.

##### Pl. 15.

In a previous communication (Virkki 1937, pp. 428-431; Pl. XXXII, fig. 1; Text-fig. 2) the spores from the specimen from Newcastle, N. S. W., shown in Pl. 15, fig. 189 were figured and briefly described along with some spores from the Salt Range, Punjab. As stated there, maceration of a small bit of the shale yielded spores in clusters, as well as single spores. Later, repeated attempts were made in vain to find a trace of a sporangium or of any other part of the fructification, which might have borne the spores. It is interesting that only spores of the *Pityosporites* type were recovered from the rock. Spores similar to these in shape and structure, though not in size, had been obtained in groups from the *Glossopteris*-bearing shale (The structure of *Glossopteris communis* Feistmantel) from the Dalton-gunj coalfield, Bihar, and from the Pali beds, Rewa (Pl. 9, fig. 125; Pl. 13, fig. 171). In all these cases no trace of the organ, which bore the spores, was obtained; but a piece of the lower cuticle of *Glossopteris communis* (The structure of *Glossopteris communis*, Feistmantel) from Bihar contained groups of these spores adhering to it.

The spores obtained from the shale from Newcastle were of two sizes, and the smaller one has been named *Pityosporites sewardi* (Virkki, 1937, p. 430), after the discoverer of *Pityosporites antarcticus* (Seward 1914, p. 23; Pl. VIII, fig. 45; 1933, pp. 311-313).

*Locality and horizon.* The specimen carried a label wherein it is stated that it belongs to the Permo-Carboniferous of Newcastle, New South Wales.



*Material.*—The dark shale carried layers of closely arranged impressions and incrustations of *Glossopteris* species, which was labelled as *G. browniana*. Satisfactory preparations of cuticles were not obtained.

#### TWO-WINGED SPORES.

Spore 84 (III, 2, a, ii, (8) ), *Pityosporites sewardi*.

Pl. 15, figs. 190B, 191, 192.

These spores do not need any further description, as spores of this species from the 20-25 ft. horizon and the Pali beds, Rewa, have been already dealt with fully. Figs 191, 192 represent the two lateral views of the spore, where fig. 192 shows the striped body above with the wings beneath, while in fig. 191 the origin of the two wings can be clearly seen. Fig. 190 represents a piece of cuticle with *P. sewardi* (fig 190B) and *Pityosporites* sp (fig. 190A) adhering to the surface. The spore marked *Pit. S. v.* presents its ventral view, where the body is below and the wings are on either side of the slit. As the spore is very dark, the slit cannot be brought out in the photograph.

An average spore has its body measuring  $27\mu$  across and the wing  $36\mu$  (transverse axis).

#### Occurrence:—

20-25 ft. horizon, Kathwai, Pl. 5, fig. 59.

Pali beds, Rewa, Pl. 13, figs. 163, 165.

Spore 85 (III, 2, a, ii, (9) ), *Pityosporites* sp.

Pl. 15, figs. 190A, 193, 194.

Description of *Pityosporites* sp. has been already given above as spores of this type are dealt with from Warchha, Bihar and Rewa.

Fig. 193 represents the dorsal view of the spore, where the striped body is seen lying above and the wings below. Fig. 194 shows the lateral view.

Measurements of an average spore; Body  $50\mu$  wing  $80\mu$ .

#### Occurrence:—

Warchha, Pl. 7, fig. 93.

Daltongunj coalfield, Bihar, Pl. 8, fig. 123.

Pali beds, Rewa, Pl. 13, fig. 166.

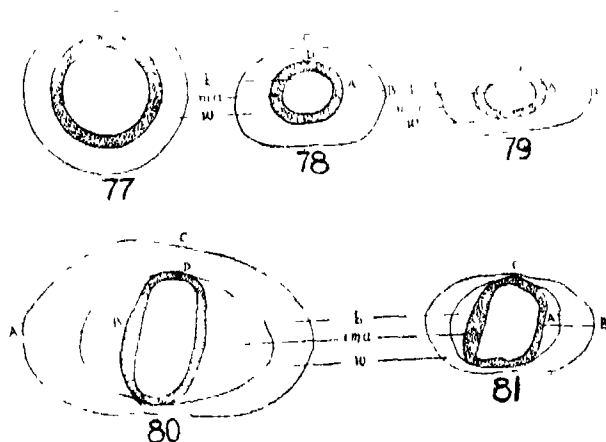
## DISCUSSION.

*Tendency of the one-winged spores to become two-winged.*

## Text-figs. 77-81.

A comparative close survey of the various spores (*Spore 42* longer—*Spore 60*) shows that the spores seem to undergo transitions of the nature illustrated in Text-figs. 77-81. Thus the one-winged type of spore in Text-fig. 77 is inclined to gradually become two-winged as in Text-fig. 81. The transverse axis (A-B) of the wing (*w.*) tends to become (in length) about double its vertical axis (C-D) as in Text-fig. 78 or about thrice or fourfold as in Text-fig. 79; and the attachment of the wing tends to transform itself from one of marginal type (*m. a.*) as in Text-figs. 78, 79 into one of the intra-marginal type (*i. m. a.*) as in Text-figs. 80, 81. Finally, there is a tendency to eliminate the vertical axis as in Text-fig. 81. All the spores from *Spore 42* to *Spore 55*, discussed in this paper, fall under the type of Text-fig. 77. *Spores 56, 57, 59 and 60* respectively, fall under the type of Text-figs. 78, 79, 80 and 81.

(*Spore 58* is excluded from the review, being badly preserved).



Text-figs. 77-81. Somewhat diagrammatic sketches of the one-winged Spores (*Spore 42*, *Spore 60*) representing the various stages, where they show a tendency to become two-winged. Fig. 77, round spore with wings of uniform width all round; attachment of the wings marginal. Fig. 78, transverse axis of the wing twice its vertical axis, which is  $1/5$  the transverse diameter of the body; attachment of the wing marginal. Fig. 79, transverse axis of the wing thrice to four times its vertical axis, which is  $1/7$  the transverse diameter of the body; attachment of the wing marginal. Figs. 80, 81, attachment of the wings intramarginal. In fig. 81 vertical axis of the wing more or less completely eliminated. *b.*—body; A—B. line representing the transverse axis of the wing; C—D. line representing the vertical axis; *i. m. a.*—intra-marginal attachment; *m. a.* marginal; *w.* wing.

*The relation of the Glossopteris flora to the glacial conglomerate.*

The climatic relation of the *Glossopteris* flora to the glacial age has been a subject of controversy for the past many years. Professor Seward (1929, p. 12). Professor Sahni (1926, p. 239; 1937, pp. 217, 218; 1938, pp. 11-16; 1939, pp. 1-6). Dr. du Toit (1924, p. 75), Jongmans and others are the strong upholders of the view that the flora co-existed with the ice. In a recent address delivered before the Biological Section of the Indian Academy of Sciences Professor Sahni (1939, pp. 1-6). has fully discussed the question on the basis of the available data. Dr. Fox (1931, pp. 7, 8, 13, 14; 1937, pp. 216, 217), who had made an extensive study of the Gondwana system, disagrees with the others. He says "the conclusion that the *Glossopteris* flora flourished in a cold climate is open to question," (Fox 1931, p. 7). When discussing the climate of the *Glossopteris* flora he, (Fox 1931, p. 14), draws our attention to some "important factors" and writes, "There is no doubt that a *Glossopteris* flora has not been found closely associated with the glacial Boulder beds of the Gondwana system. In Kashmir and the Punjab Salt Range the *Gangamopteris* (with *Glossopteris*) horizon occurs at a considerably higher horizon than the Boulder bed. The conclusion is that the climate of the Ice Age was not favourable to the *Glossopteris* flora". The evidences (Fox 1931, pp. 7, 8, also see p. 13) set forth by him are that "The bedded character of the Talchir sediments above the boulder bed suggests deposition under water and also the disappearance of the ice. The remains of fossil plants are only found in the topmost beds of the Talchir series and might well be interpreted as indicating a temperate climate". In 1931, when Dr. Fox made these statements, evidences were already available pointing to the existence of a flora associated with the Boulder bed. In Africa as early as 1921, Dr. T. N. Leslie (1921, p. 23), had recorded the occurrence of fairly well preserved impressions of *Gangamopteris*, one of which was photographed by Seward and Walton. (1923, Pl. 23, fig 23). This discovery was followed by another similar find by Dr. du Toit (du Toit 1924, p. 75), from another place, Strydenburg, in the same region. In 1922 Süssmilch (1922, p. 144), made mention of the occurrence of *Gangamopteris* and *Schizoneura* in beds interstratified with the glacials at Bacchus Marsh in Australia.

Till last year there was no evidence from India in favour of the view that the *Glossopteris* flora co-existed with the ice. The shales collected from 1½ ft. and 4½ ft. respectively, above the Talchir Boulder bed yielded various kinds of spores, both winged and unwinged. Similar, if not identical, spores were also found in the 20-25 ft. horizon at Kathwai, the horizon below the Middle Productus Limestone (Warchha), the Daltongunj coalfield (Bihar)

and the Pali beds (Rewa). In these horizons only members of the *Glossopteris* flora are reported to have been found.

It is not easy to assign a definite age to the 1½ ft. horizon, when even the age of the underlying Boulder bed itself is in doubt. In a letter dated the 12th November 1937, Mr. Wadia expresses the opinion (see above) that the Boulder bed exposed in a section at Kathwa is not the original one, but that it consists of reassorted boulders. Yet, according to him, the difference in age between the original glacial bed and the reassorted one is not considerable. As regards the sediments of the 1½ ft. horizon Professor Sahni has said (see quotation above) that this lowermost plant-bearing horizon may be taken to be approximately of the same geological age as the glacial bed. It, therefore, seems likely that the *Glossopteris* flora was already in existence even during the glacial epoch.

A futile search was made for spores in the glacial matrix from the Salt Range. As already stated samples of the glacial tillite from Kashmir, from several localities in Australia and from two localities in Africa were also tried; only the sample from Bacchus Marsh, Victoria, yielded spores and other organic matter. The fact that most of the spores showed a close resemblance with those already described from the other localities, evidently shows that the spores from the Bacchus Marsh glacial tillite belong to members of the *Glossopteris* flora. These evidences strongly support the view that the *Glossopteris* flora of the Southern continent was contemporaneous with the Ice Age. As yet, we have no such evidence from S. America.

The origin of the *Glossopteris* flora is not known. As Professor Sahni (1926, pp. 239, 240; 1938, p. 14; 1939, p. 3) points out "at least some of the lines of descent can be traced back into the pre-glacial flora." The glaciation that followed probably wiped out many of the old representatives, and the few that survived the cold climate later multiplied, reaching their height of development in the Permian. The spores too are found to be fewer in number and variety in the glacial matrix than in the higher horizons; without making a quantitative study of the spores in the different horizons it would be presumptuous to make an estimate of the gradual increase of the flora from the glacial epoch to the later periods.

At present nothing definite can be said regarding the nature of the pre-glacial flora. As suggested by Professor Sahni it will be worth while to make a search for spores in the beds immediately underlying the glacial conglomerate.

## ACKNOWLEDGMENTS.

It is with deep gratitude that I take this opportunity to thank Professor B. Sahni, F.R.S., for suggesting this investigation and for the inspiration and guidance he has given me throughout the course of this work. It is needless to say that had it not been for his valuable help this work would not have reached the present stage. I am grateful to him for having placed at my disposal the material collected by Mr. Gee and others, as well as the samples of glacial tillite which he obtained from the Geological Survey of India, the British Museum and from various localities in Australia and S. Africa. I am highly obliged to Dr. K. Jacob for his invaluable help and suggestions which I have received throughout the course of this work. My thanks are also due to the authorities of the Women's Christian College, for the facilities given me to carry out a part of the work at Madras during the holidays.

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## EXPLANATION OF PLATES.

All figures are from untouched photographs. Panchromatic plates were used in the case of photo-micrographs.

Each slide from where spores are figured and described carries a label denoting the number of the slide (in red ink), the number of the specimen from where the preparations were made, its locality and horizon. The location of each spore on the slide is indicated by three numbers, thus: 65-52·4/85·1. The first (65) designates the number of the slide, the second (52·4) the ordinate and the third (85·1) the abscissa reading of the mechanical stage.

The following abbreviations are used in giving the size of the spores:—

b.—Body; b.w.—body wall; l.s.—largest spore; r.—rim; s.—spore; s.m.—smallest spore; t.a.—transverse axis of the wing; v.a.—vertical axis of the wing; w.—wing.

It may be mentioned here that in certain cases the text-figures will not appear true to their photographs. This is due to the difference in focussing when drawing the figures;

\*Not accessible to the author.

in certain cases, moreover, the spores are not stationary.

*The figured specimens are preserved in the Department of Botany, Lucknow University.*

*The measurements of the spores are given in  $\mu$ . Unless otherwise stated all spores are magnified 380 times*

# PLATE 1.

Kathwai,  $1\frac{1}{2}$  ft. horizon.

FIGS. 1, 2. Photographs of the section exposed at Kathwai. Fig. 1 shows the section from where the shales  $1\frac{1}{2}$  ft and  $4\frac{1}{2}$  ft respectively, above the Talchir Boulder bed were collected. The arrow marks the  $1\frac{1}{2}$  ft. horizon and X marks the position from where the shales of the  $1\frac{1}{2}$  ft. horizon were obtained. The hammer rests on a boulder with the Purple Sandstone below and the Speckled Sandstone above. Fig. 2 shows two boulders (with the case of a camera stand below). *B.*—Talchir Boulder, *c.s.*—Carbonaceous shale; *p.s.*—Purple Sandstone, *s.s.*—Sandstone.

FIGS. 3-9. Spores from the  $1\frac{1}{2}$  ft. horizon (marked X).

		Size.	Location.
FIG. 3.	SPORE 1	32.4×28	65-52 4/85 1
FIG. 4.	SPORE 5, bilateral tetrad just separating.	70×35	57-51.9/87.0
FIG. 5.	SPORE 5, individuals of different sizes.	72×37	58-50.4/87.7
FIG. 6.	SPORE 13, slit with rounded ends	90×85	74-43.3/97.6
FIG. 7.	SPORE 13	82	58-43.2/93.4
FIG. 8.	SPORE 36	<i>s.</i> —71; <i>b.</i> —44	89-30 4/82.8
FIG. 9.	SPORE 40, <i>sl.</i> —slit (crescent-shaped).	<i>b.</i> —66×50; <i>r.</i> —8, <i>t.a.</i> —22; <i>v.a.</i> —15	57-58.7/93.7

# PLATE 2.

Kathwai,  $1\frac{1}{2}$  ft. horizon.

		Size.	Location.
FIG. 10.	SPORE 42	<i>s.</i> —68×52; <i>b.</i> — 56×38; <i>r.</i> —10	89-58.2/99.9
FIG. 11.	SPORE 45	<i>s.</i> —88; <i>b.</i> —64 <i>r.</i> —4	60-22.5/88.9
FIG. 12.	SPORE 45	<i>s.</i> —97×79; <i>b.</i> — 79×57; <i>r.</i> —4	65-22.9/91.0
FIG. 13.	SPORE 47	<i>s.</i> —74; <i>b.</i> —50; <i>r.</i> —6	69-62.1/10.5
FIG. 14.	SPORE 49	<i>s.</i> —101×98; <i>b.</i> — 64×61; <i>r.</i> —7	66-61.5/92.0
FIG. 15.	SPORE 51	<i>s.</i> —172; <i>b.</i> — 124×97; <i>r.</i> —8	75-32.7/92.5
FIG. 16.	SPORE 53	<i>b.</i> —95×76; <i>r.</i> —11; <i>t.a.</i> —22; <i>v.a.</i> —10	58-35.8/93.9



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FIG. 17. SPORE 64	...	...	b.—41·5; t. a.—35; v. a.—60	74-49·8·3/102·9
FIG. 18. SPORE 64	...	..	b.—45; t. a.—38; v. a.—70.	89-31·2/96·2
FIG. 19. SPORE 64	...	.	b.—56×42; t. a.— 45; v. a.—70	58-34·5/99·1
FIG. 20. SPORE 67	..	...	b.—34×22; t. a.— 44; v. a.—38	62-53·8/94·7
FIG. 21. SPORE 86, <i>Pityosporites</i> sp.			b.—35×26; t. a.— 27	61-46·8/89·3
FIG. 22. SPORE 87, <i>Pityosporites</i> sp.	...	...	b.—42×40; t. a.— 37	58-40·8/84·9
FIG. 23. SPORE 87, <i>Pityosporites</i> sp.	...	...	b.—45×40, t. a.—37.	62-38·2/101·0

PLATE 3.

Kathwai, 4½ ft. horizon (figs. 24-30).

		Size.	Location.
FIG. 24. SPORE 1	.	s.—46×38	56-64·4/91·2
FIG. 25. SPORE 30	..	s.—138×98	56-25·9/102·9
FIG. 26. SPORE 35, b.—body, r.—rim	..	s.—150×100; b.—74×48	52-40·3/89·5
FIG. 27. SPORE 45	..	s.—94; b.—74; r.—3	56-40·8/102·9
FIG. 28. SPORE 47	...	s.—65×58; b.— 45×42; r.—6	56-49·0/89·6
FIG. 29. SPORE 71, b.—body. w.—wing	..	b.—54×34; t. a.— 39; v. a.—70	56-60·2/88·8
FIG. 30. SPORE 73	..	b.—100×60; t. a.— 55; v. a.—76	56-64·6/91·5

Kathwai, 20-25 ft. horizon (figs. 31-36).

The spores shown in figs. 33, 35, 36 are from the specimen shown in Pl. 1, fig. 8, of my paper. "A lower Gondwana flora from the Salt Range, Punjab" (Virkki, 1937); that in fig. 31 from the specimen represented in Pl. 2, fig. 11; and those in figs. 32, 34 from the specimen shown in Pl. 7, fig. 51 of the same paper.

		Size.	Location.
FIG. 31. SPORE 5, individuals (in two pairs) are of different sizes.		l. s.—68·5×42·5; s. s.—61×17	27-26·7/100·0
FIG. 32. SPORE 5, individuals separated	...	l. s.—86×36; s. s.— 70×28	38-49·8/102·6
FIG. 33. SPORE 5, individual spore	..	s.—110×59; b. w.—15	20-21·4/91·3
FIG. 34. SPORE 10	...	s.—66×46	36-51·0/85·4
FIG. 35. SPORE 12	...	s.—41×40	28-54·8/98·5
FIG. 36. SPORE 16	...	s.—40×38; b. w.—8	21-35·4/95·9

## PLATE 4.

Kathwai, 20-25 ft. horizon.

The spores shown in figs. 37, 38, 41-45, 47 are from the specimen shown in Pl. 1, fig. 8 of my paper "A Lower Gondwana flora from the Salt Range, Punjab" (*Virkki 1937*). The one in fig. 40 is from the specimen shown in Pl. 2, fig. 11, and those in figs. 39, 46, 48 are from the specimen represented in Pl. 7, fig. 51 of the same paper.

			Size.	Location.
FIG 37	SPORE 17	...	s.—68; b. w.—4	20-62·3/89·8
FIG 38	SPORE 18	.	s.—58, b. w.—3	23-46·4/88·5
FIG 39	SPORE 19	..	s.—80, 74, 62 (axes)	39-64 3/89·8
FIG 40	SPORE 0	...	s.—67	28-47 7/89·6
FIG 41.	SPORE 23	...	s.—40, 34, 32	24-34 4/98
FIG 42	SPORE 31, body is faintly indicated	...	s.—164×123	26-45 7/82·6
FIG. 43.	SPORE 31	...	s.—166×120	20-57·6/96·5
FIG. 44.	SPORE 32	...	s.—253×176	20-34·2/96·1
FIG. 45.	SPORE 48	...	s.—100; b.—70	25-63·9/98·9
FIG 46	SPORE 49	.	s.—116×110; b.—79; r.—9	89-24·7/87·2
FIG 47	SPORE 49	...	s.—118; b.—83×80	23-24 3/84
FIG 48	SPORE 51	...	s.—176×151; b.— 126×116; r.—12	89-26 9/82·2

## PLATE 5.

Kathwai, 20-25 ft. horizon.

The spores in figs 50-52, 54 are from the specimen represented in Pl. 1, fig. 8 of my paper "A Lower Gondwana flora from the Salt Range, Punjab" (*Virkki 1937*). Those in figs. 49, 53, 55, 59-61, are from the specimen in Pl. 2, fig. 11; the spores in figs. 56-58, are from the specimen shown in Pl. 7, fig. 51 of the same paper.

			Size.	Location.
FIG 49.	SPORE 52	...	s.—234×198	30-22 4/89·4
FIG. 50.	SPORE 53	...	s.—80; b.—48	21-34 7/80·9
FIG. 51.	SPORE 58	...	s.—78×74; b.—42; r.—4	25-58 5/84·5
FIG. 52.	SPORE 54	...	s.—146; b.—82×74; r.—10	21-49·7/88·5
FIG. 53.	SPORE 61	...	b.—74×70; t. a.— 82; v. a.—62	29-28·2/85·0
FIG. 54.	SPORE 62	...	b.—42; t. a.—22; v. a.—50	20-84·3/100·7
FIG. 55.	SPORE 64	...	b.—63×58; t. a.— 48; v. a.—79	34-39·3/98·7

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FIG. 56. SPORE 65	..	... b —107×100, t a.—74; v a.—124	39-57·3/98·4
FIG. 57. SPORE 68	...	. b.—42×36; t a —70; v. a.—74	39-23·6/90·4
FIG. 58. SPORE 83, <i>Pityosporites</i> sp.	.	b —80, b w —5 5, t. a.—48	40-32·8/84
FIG. 59. SPORE 84, <i>Pityosporites seawardi</i>	b —31×27; b. w —4; t. a.—32		34-44/97·3
FIG. 60. SPORE 87, <i>Pityosporites</i> sp.	...	b —40·5×31, b w.—2; t. a.—40	27-60·5/97 5
FIG. 61. SPORE 95	...	... b.—58×46, w.—17	31-17 5/87·5

## PLATE 6.

Warchha.

The tracheid and spores shown in this plate were obtained from the specimen represented in Pl. 10 fig. 73 of my paper "A Lower Gondwana flora from the Salt Range, Punjab" (Virkki 1937).

		Size.	Location.
FIG. 62. Tracheids	..	.....	6-57·1/80·5
FIG. 63. SPORE 5, compact tetrad	.	s.—65×33	3 46 3/96·4
FIG. 64. SPORE 5	...	s.—58×26	7-27·5/97 3
FIG. 65. SPORE 5, individual	..	s.—68×36; b w.—7	4-5·5/93·4
FIG. 66. SPORE 6, 1 <sub>1</sub> 1 <sub>4</sub> four big lobes, ...		50 (each lobe)	7-30·2/100 68
		s.—1 <sub>1</sub> s.—1 <sub>4</sub> four small lobes	
FIG. 67. SPORE 9	...	s.—56	4-17 3/91 9
FIG. 68. SPORE 15	...	s.—104·5×102	1-50 4/83·6
FIG. 69. SPORE 21	...	s.—62	5-25 3/91 6
FIG. 70. SPORE 22	...	s.—74; b w—4	2-85 6/98·8
FIG. 71. SPORE 28, group of four spores		s —31	9-25/91·0
FIG. 72. SPORE 23	...	s.—30	7-19 1/95·4
FIG. 73. SPORE 23	...	s.—20	4-58 4/93·5
FIG. 74. SPORE 24	...	s.—61	3-47 6/91·5
FIG. 75. SPORE 25	...	s.—50	7-25·0/100 0.
FIG. 76. SPORE 26	...	s.—60	8-60·7/95 0.
FIG. 77. SPORE 27	...	s —68	4-23 2/91·5.
FIG. 78. SPORE 34	...	s.—168×118, b —92×75; r.—10,	4-62·5/97 6.
FIG. 79. SPORE 34	...	s.—157×112; b.—85×78; r.—8.	5-36·4/88·6.
FIG. 80. SPORE 40 st.—crescent shaped slit; r.—rim.		s.—121×88; b.—62×52; r.—10.	2-24·6/103·0.
FIG. 81. SPORE 46. st.—triradiate slit	...	s.—118; b.—100×92; r.—9	7-35·0/92·3.
FIG. 82. SPORE 56	...	b.—56×46; r.—12, t. a.—23·2; v. a.—11	4-57·8/81·2.

FIG. 83. SPORE 60	...	...	b.—52; r.—6; t. a.—20·5	3-38·2/85·2.
FIG. 84. SPORE 64	...	...	b.—50; t. a.—42·5;	
			v. a.—67,	7-23·0/84·4.
FIG. 85. SPORE 66	...	...	b.—32×29; b. w.—4;	
			t. a.—56; v. a.—38·5	7-57·4/99·4.
FIG. 86. SPORE 66	...	...	b.—35×34; b. w.—4,	
			t. a.—48; v. a.—48,	7-85·7/88·8.

PLATE 7.

Warchha (figs. 87-99).

		Size.	Location.
FIG. 87. SPORE 69	..	b.—80×66 4	2-29·7/96·5
FIG. 88. SPORE 74, sl.—longitudinal slit;		b.—40×26; t. a. 16 5,	
r. rim.		v. a.—40.	2-35 8/89·2.
FIG. 89. SPORE 75, sl.—longitudinal slit,		b.—47×28; r.—10,	
r.—rim.		t. a.—27 5, v. a. 47.	3-38 6/103 0
FIG. 90. SPORE 79, <i>Pityosporites</i> sp	.	b.—70×60, t. a.—41	4-53 0/100·8.
FIG. 91. SPORE 80, <i>Pityosporites</i> sp	..	b.—69; b. w.—4; t. a.—50	2-44·0/104 1.
FIG. 92. SPORE 83, <i>Pityosporites</i> sp	.	b.—78×74, t. a.—54	2-44·0/104·1.
FIG. 93. SPORE 85, <i>Pityosporites</i> sp	..	b.—41×29; t. a.—34	12-28·0/95·4
FIG. 94. SPORE 87, <i>Pityosporites</i> sp,		b.—42, t. a.—48	3 39·8/91·5.
ventral view.			
FIG. 95. SPORE 87, <i>Pityosporites</i> sp,	..		7-19·1/95 4.
lateral view.			
FIG. 96. SPORE 92, <i>Pityosporites</i> sp.,		b.—40, b. w.—3; t. a.—56	2-60·8/97·9.
lateral view			
FIG. 97. SPORE 94, b.—body; w <sub>1</sub> —w <sub>3</sub> —		b.—30·4, t. a.—27	3-33·6/100·7
three wings.			
FIG. 98. SPORE 96	...	b.—50; w.—29 (across)	10-24·0/98 1
FIG. 99. SPORE 97	...	b.—60×48; w.—38	4-37·2/98·2

Jhallowah (figs 100-105).

Spores shown in figs. 100-105 were obtained during the cuticular preparation of *Glossopteris* sp. d represented in Pl. 15, fig. 117 of my paper "A Lower Gondwana flora from the Salt Range, Punjab" (Virkki 1937).

		Size.	Location.
FIG. 100. SPORE 11	...	s.—74×60	17-60·5/90·0.
FIG. 101. SPORE 20	...	s.—52	17-37·4/85·4.
FIG. 102. SPORE 31	...	s.—168×123; b.—98×84	18-27 0/87·9.
FIG. 103. SPORE 41	...	b.—50; b. w.—6, w.—6	17-41·7/98·3
FIG. 104. SPORE 76, ventral view; slit clear.		b.—67×63; r.—10;	
		t. a.—82	17-44·0/93·5.
FIG. 105. SPORE 87, <i>Pityosporites</i> sp., cen-		b.—52×49; v. a.—3;	15-37 6/98·6
tral view		t. a.—47.	

## PLATE 8

## Daltongunj Coalfield, Bihar

The tracheid and spores shown in this plate were obtained from the shale represented in Pl. 1, fig. 1, in my paper "The structure of the cuticle of *Glossopteris communis* Feistmantel" (Virkki 1937).

			Size.	Location.
FIG. 106.	Tracheid	...	...	129-47·5/93·2.
FIG. 107.	SPORE 3	...	s.—146×125	124-35 3/92·0.
FIG. 108.	SPORE 28	..	s.—77×64, b.—48×39	128-68·3/88 6.
FIG. 109.	SPORE 29	...	s.—96×92; b.—47×42	123-20 7/85·7.
FIG 110.	SPORE 43	...	s.—76×62; b.—54×41; r.—8	127-52·8/95·0.
FIG 111.	SPORE 43, this is taken from the upper cuticle of the bit shown in Pl. 1, fig 4	...	s.—80×62, b.—58×46, r.—9.	134
FIG. 112.	SPORE 44	...	s.—114×110; b.—79×70; r.—15	123-59 0/94·5.
FIG. 113.	SPORE 45	...	s.—94×76; b.—69×50; r.—8	129-39·1/87 0.
FIG 114.	SPORE 45	...	s.—105×94; b.—75×65	131-59·2/187·2.
FIG. 115.	SPORE 45	...	s.—100×88; b.—86×78	128-30·4/83·0.
FIG. 116.	SPORE 48	...	s.—93×86; b.—64	181-59 5/84·4.
FIG. 117.	SPORE 49	...	s.—129×110; b.— 90×72; r.—16.	129-39·7/86·2.
FIG. 118.	SPORE 70	...	b.—38×24; t. a.— 88; v. a.—68.	129-27·3/93·1.
FIG. 119.	SPORE 77, <i>Pityosporites</i> sp.	...	b.—36×32; t. a.—18	129-21 2/98 5.
FIG. 120.	SPORE 81, <i>Pityosporites</i> sp.	...	b.—12; t. a.—27	129-34·2/83·5
FIG. 121.	SPORE 81, <i>Pityosporites</i> sp.	...	b.—54×48; t. a.—32	132-34·0/98·4.
FIG. 122.	SPORE 81, <i>Pityosporites</i> sp.	...	b.—52×48; t. a.—39	129-22 8/98·3.
FIG. 123.	SPORE 85, <i>Pityosporites</i> sp.	...	b.—32×30, t. a.—26.	127-43 8/96·2.
FIG. 124.	SPORE 88, <i>Pityosporites</i> sp.	...	b.—43×33; t. a.—45	132-38·0/98 1.

## PLATE 9

## Pali Beds, Rewa.

The tracheids and stoma in figs. 126, 127 were obtained from the point marked with a white label in fig. 125.

FIG. 125. The piece of shale from which the spores and other organic remains were obtained. The region from where the matrix was removed is indicated by a white triangular label. The shale carries a very badly preserved impression of *Glossopteris* sp. Slightly reduced.

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FIG. 126. An isolated stoma obtained along with the spores. The six subsidiary cells with overhanging papillae are clear. Guard cells and stomatal opening are not preserved.  $\times 520$  (location—94-42·5/98·4).

FIG. 127. Tracheids with a portion of a medullary ray  $\times 260$  (location—91-48 5/85·9).

## PLATE 10

### Pali Beds, Rewa

The spores here figured were obtained from the point marked with a white label in Pl. 9, fig. 125.

		Size.	Location.
FIG. 128. SPORE 1	...	s.—88 $\times$ 28	90-53 1/97·0
FIG. 129. SPORE 2	...	s.—43; b. w.—2	94·5·8/90·5.
FIG. 130. SPORE 4	...	s.—230 $\times$ 194	105-59·3/93·2.
FIG. 131. SPORE 4	...	s.—252 $\times$ 201	94-62 8/36·3
FIG. 132. SPORE 7	...	s.—73 $\times$ 68	94-44·5/102·7.
FIG. 133. SPORE 8	...	Spore not traceable	.
FIG. 134. SPORE 37	...	s.—184 $\times$ 130; b.— 136 $\times$ 106	103-62·5/84·5.
FIG. 135. SPORE 38	...	Spore not traceable	...
FIG. 136. SPORE 38	...	s.—230 $\times$ 176; b.— 162 $\times$ 124	90-42 4/88 7

## PLATE 11.

### Pali Beds, Rewa.

The spores here figured were obtained from the point marked with the white label in Pl. 9, fig. 125.

		Size.	Location.
FIG. 137. SPORE 38, sl.—slit	...	s.—235 $\times$ 228; (—160 $\times$ 142	103-37·2/84·1
FIG. 138. SPORE 38	...	s.—270 $\times$ 220; b.—207 $\times$ 130	91-53·0/94·6
FIG. 139. SPORE 39	...	s.—227 $\times$ 160; b.—144 $\times$ 96	100-50·0/90·9
FIG. 140. SPORE 42	...	s.—56 $\times$ 49; b.—44; r.—8	99-45·0/96·7
FIG. 141. SPORE 43	...	s.—74 $\times$ 68; b.—54 $\times$ 51; r.—8	98-56·8/87·4
FIG. 142. SPORE 44	...	s.—91; b.—78 $\times$ 68; r.—9	99-22·1/91·8
FIG. 143. SPORE 49	...	s.—106; b.—74; r.—10	96-33·3/94·6

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FIG. 144. SPORE 49	... s.—112×108; b.—76; r.—9	92-46.6/98.0
FIG. 145. SPORE 49	... s.—118; b.—87; r.—11	97-89.7/88.9
FIG. 146. SPORE 50	... s.—140×120; b.—100×75; r.—12	92 30.6/90.5

## PLATE 12.

Pali Beds, Rewa.

\*The spores figured here were obtained from the point marked with the white label in Pl. 9, fig. 125

	Size.	Location.
FIG. 147. SPORE 51	s.—170×150, b.—116×104, r.—14	97-21.8/87.7
FIG. 148. SPORE 53	.. s.—92×87, b.—55	101-34.1/90.5
FIG. 149. SPORE 53	... s.—92×88, b.—50, r.—8	101-44.6/89.7
FIG. 150. SPORE 55, b—body	... s.—228×176, b.—117×109	96-33.0/89.7
FIG. 151. SPORE 56	. b.—48×42; r.—7; t. a.—7; v. a.—6	105-53.4/94.5
FIG. 152. SPORE 56	... Not traceable	...
FIG. 153. SPORE 57	... b.—59×37; r.—9; t. a.—25.5; v. a.—7.5	92-59.3/99.3
FIG. 154. SPORE 60, sl.—triradiate slit	... b.—68×59; t. a.—20; v. a.—8	94-29.6/87.2
FIG. 155. SPORE 68	.. b.—88×80; t. a.—58; v. a.—120	101-22.0/101.3
FIG. 156. SPORE 68	... b.—34; t. a.—56; v. c.—74	98-58.3/94.5
FIG. 157. SPORE 69	... b.—67; w.—99.5×70	90-29.9/84.4
FIG. 158. SPORE 72	... b.—58×26; t. a.—68	92-38.0/99.6

## PLATE 13

Pali Beds, Rewa

The spores figured in this plate were obtained from the point marked with a white label in Pl. 9, fig. 125.

	Size.	Location.
FIG. 159. SPORE 78 <i>Pityosporites</i> sp. ...	<i>b.</i> —50×32; <i>t. a.</i> —26	99-31·3/97.2
FIG. 160. SPORE 82, <i>Pityosporites</i> sp. .	<i>b.</i> —58, <i>t. a.</i> —41	92-40·8/84.5
FIG. 161. SPORE 82, <i>Pityosporites</i> sp. ...	<i>b.</i> —67; <i>t. a.</i> —44	95-44·9/100.4
FIG. 162. SPORE 83, <i>Pityosporites</i> sp. ...	<i>b.</i> —74×59; <i>t. a.</i> —52	91-26·2/90.0
FIG. 163. SPORE 84, <i>Pityosporites seawardi</i>	<i>b.</i> —28×27; <i>b. w.</i> —1, <i>t. a.</i> —25	104-38·4/96.0
FIG. 164. SPORE 84, <i>Pityosporites seawardi</i>	<i>b.</i> —28×26; <i>b. w.</i> —2, <i>t. a.</i> —27	92-36 5/100.0
FIG. 165. SPORE 84, <i>Pityosporites seawardi</i>	<i>b.</i> —28; <i>t. a.</i> —23	95-66·5/88.7
FIG. 166. SPORE 85, <i>Pityosporites</i> sp. .	<i>b.</i> —32; <i>t. a.</i> —34	96-36·9/89.9
FIG. 167. SPORE 86, <i>Pityosporites</i> sp.	Not traceable	...
FIG. 168. SPORE 87, <i>Pityosporites</i> sp.	<i>b.</i> —41; <i>b. w.</i> —3, <i>t. a.</i> —42	95-32·1/96.0
FIG. 169. SPORE 87, <i>Pityosporites</i> sp. ...	Not traceable	...
FIG. 170. SPORE 87, <i>Pityosporites</i> sp. ..	<i>b.</i> —54×464, <i>t. a.</i> —36	103-45·5/99.0
FIG. 171. SPORE 87, <i>Pityosporites</i> sp group	... of spores, one of which <i>Pit.</i> , is enlarged in fig. 172	98-54·2/89.7
FIG. 172. SPORE 87, <i>Pityosporites</i> sp <i>Pit.</i>	<i>b.</i> —62×44, enlarged from fig. 171 <i>t. a.</i> —44	98-54·2/89.7
FIG. 173. SPORE 89, <i>Pityosporites</i> sp. ...	<i>b.</i> —50×42; <i>t. a.</i> —55	106-53·8/91.6
FIG. 174. SPORE 90, <i>Pityosporites</i> sp. ..	<i>b.</i> —43—38, <i>t. a.</i> —47	94-64·6/15.5
FIG. 175. SPORE 91, <i>Pityosporites</i> sp....	<i>b.</i> —44×40; <i>t. a.</i> —60	92-55·6/84 9
	<i>sl.</i> longitudinal slit	
FIG. 176. SPORE 93, <i>sl</i> slit with thickened margin	<i>b.</i> —60×48; <i>w.</i> —87×66	91-47·2/90.7

## PLATE 14.

## Bacchus Marsh, Victoria.

The spores and other organic remains represented in this plate were obtained from a piece of glacial tillite from Bacchus Marsh which was kindly sent to Professor Sahni by the authorities of the British Museum. The sample of tillite bore the label "Tillite (Permo-Carboniferous), Coimada Creek, Bacchus Marsh, Victoria, off B. M. 1925, 965."

A series of spores from this sample will be presented to the British Museum. The figured specimens are preserved in the Botany Department, Lucknow University.

	Size.	Location.
FIG. 177. Tracheids	... ..	117-57·1/91.5
FIG. 178. SPORE 1	... <i>s.</i> —38×32	116-51·2/102.4
FIG. 179. SPORE 14	... <i>s.</i> —56×38	118-52·6/101.0
FIG. 180. SPORE 33	... <i>s.</i> —146×69	116-53·2/103.6
	<i>b.</i> —101×59	



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FIG. 181. SPORE 43	... s.—74×53; b.—48 ×36; r.—9	120-47.3/92.0
FIG. 182. SPORE 43	.. s.—74×68; b.—49 ×45; r.—8	120-47.1/91.3
FIG. 183. SPORE 43	.. s.—86×72; b.—53×47; r.—7	117-59.1/94.1
FIG. 184. SPORE 48	... s.—96×87; b.—72×63; r.—13	115-41.0/92.0
FIG. 185. SPORE 49	s.—118×109, b.—83×68; r.—12	117-54.6/86.6
FIG. 186. SPORE 50	.. s.—150×114; b.—108×72; r.—14	121-39.0/85.8
FIG. 187. SPORE 59	s.—197×126, b.—106×94	120-38.4/87.1
FIG. 188. Animal remains (probably part of the antenna of an insect)	...	122

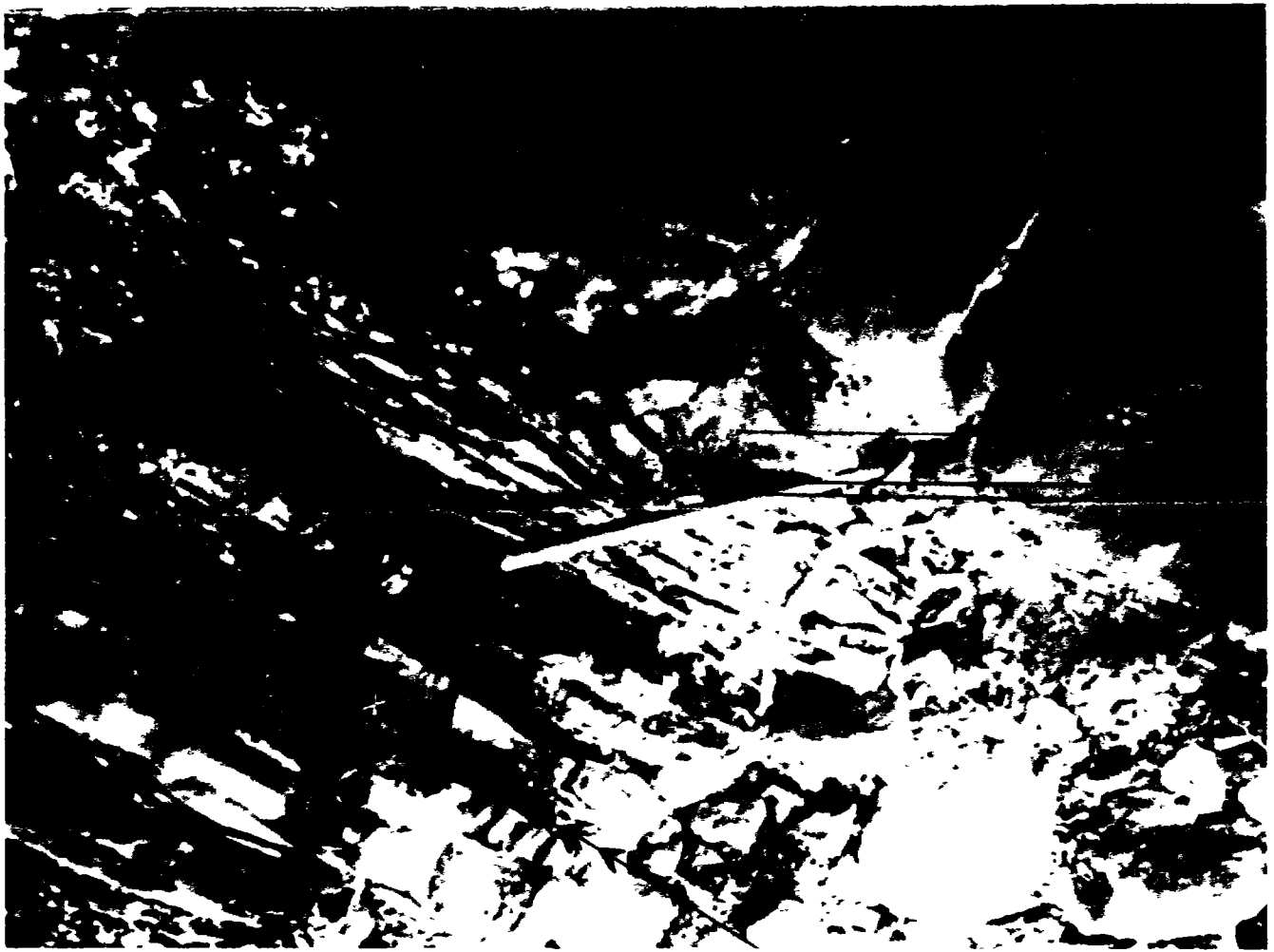
## PLATE 15.

Newcastle, New South Wales

The spores in this plate were obtained by macerating a piece of the shale represented in fig. 189.

Unless otherwise stated, all × 400.

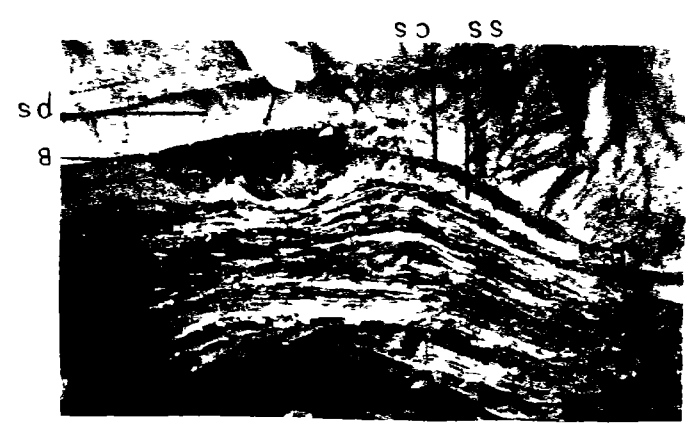
- FIG. 189 Shale with impressions and incrustations of a species of *Glossopteris* labelled as *G. browniana*. Maceration of a piece of the shale yielded spores in great quantities. All of them were either *Pityosporites seawardi* or *Pityosporites* sp. A few of them are shown in figs. 190-194 Permo-Carboniferous of Newcastle, New South Wales. Slightly reduced.
- FIG. 190. A-Spore 85, *Pityosporites* sp.; B-Spore 84, *Pityosporites seawardi* adhering to the surface of a piece of cuticle. v. *Pityosporites seawardi* presenting its ventral view.
- FIG. 191. SPORE 84, *Pityosporites seawardi*, one of the lateral views is presented ...
- FIG. 192. SPORE 84. *Pityosporites seawardi*. lateral view ...
- FIG. 193. SPORE 85, *Pityosporites* sp., dorsal view
- FIG. 194 SPORE 85, *Pityosporites* sp., lateral view ...



C. Virkki: Spores from the Lower Gondwanas of India and Australia

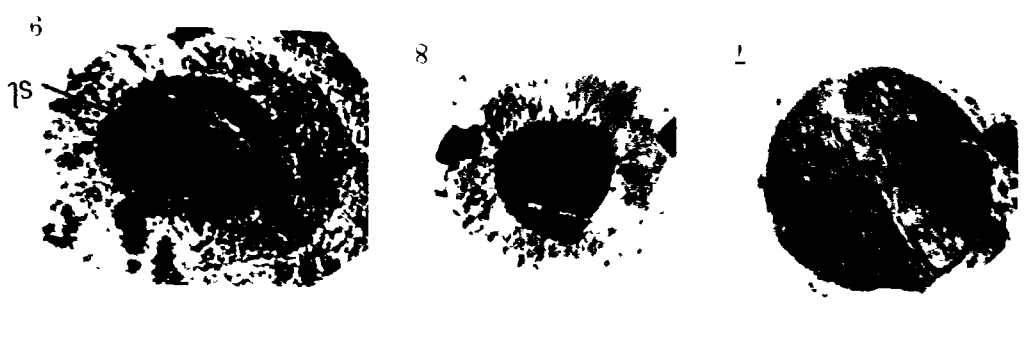
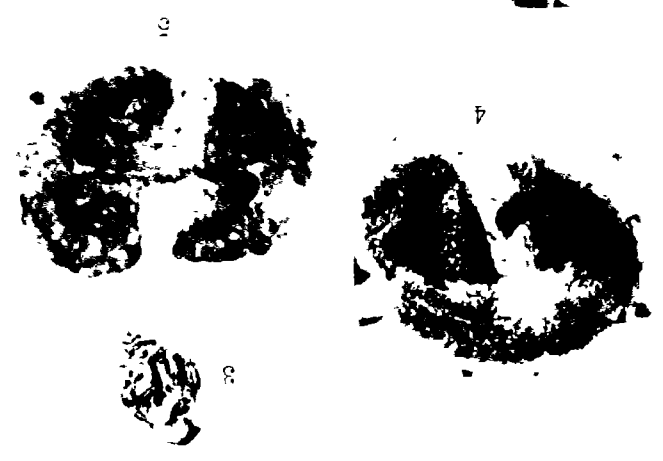
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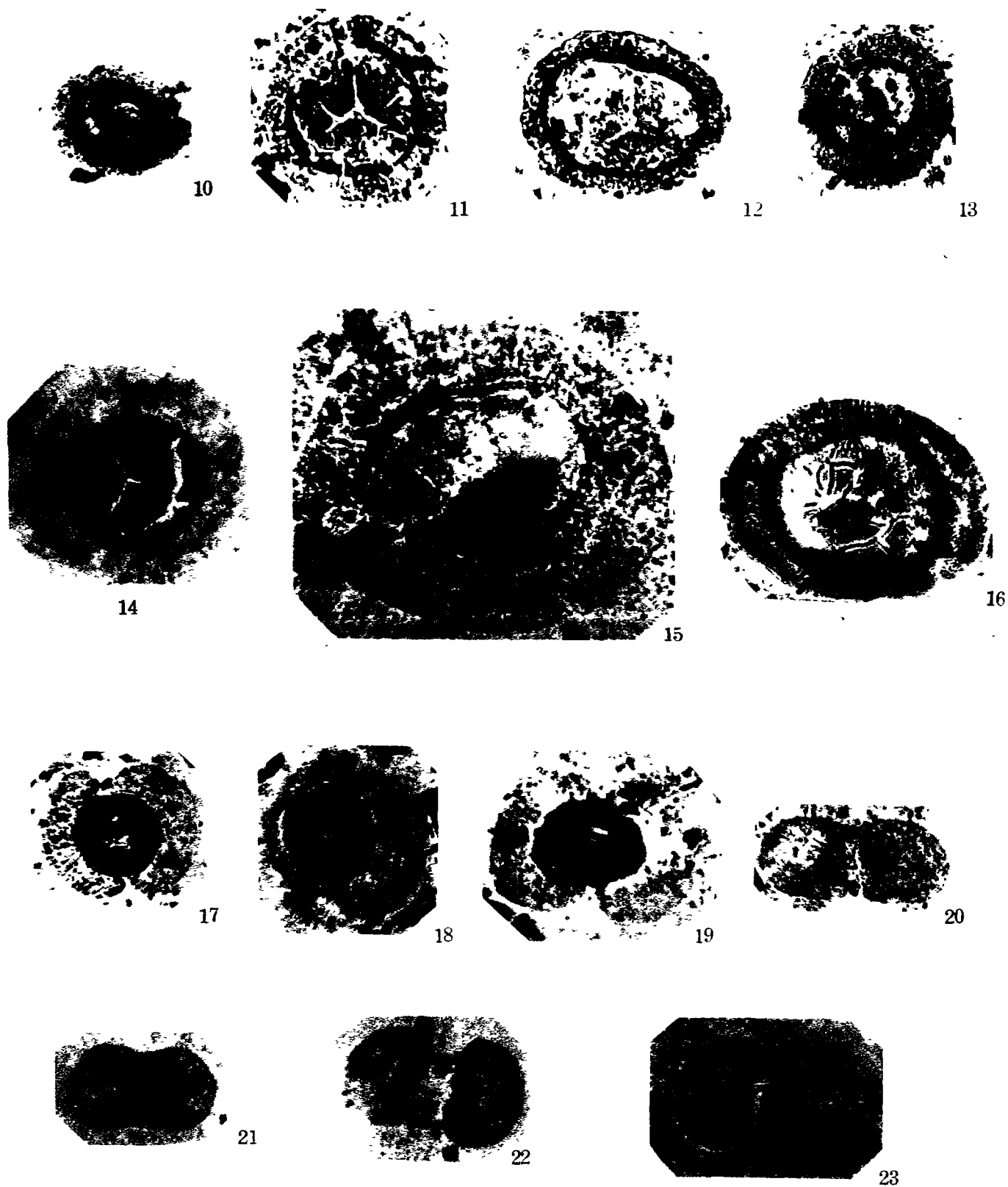


C. Virkki photo

KATHWAI, SALT RANGE.

Figs 3-9. Spores from 1 1/2 ft. above the Talchir Boulder Bed



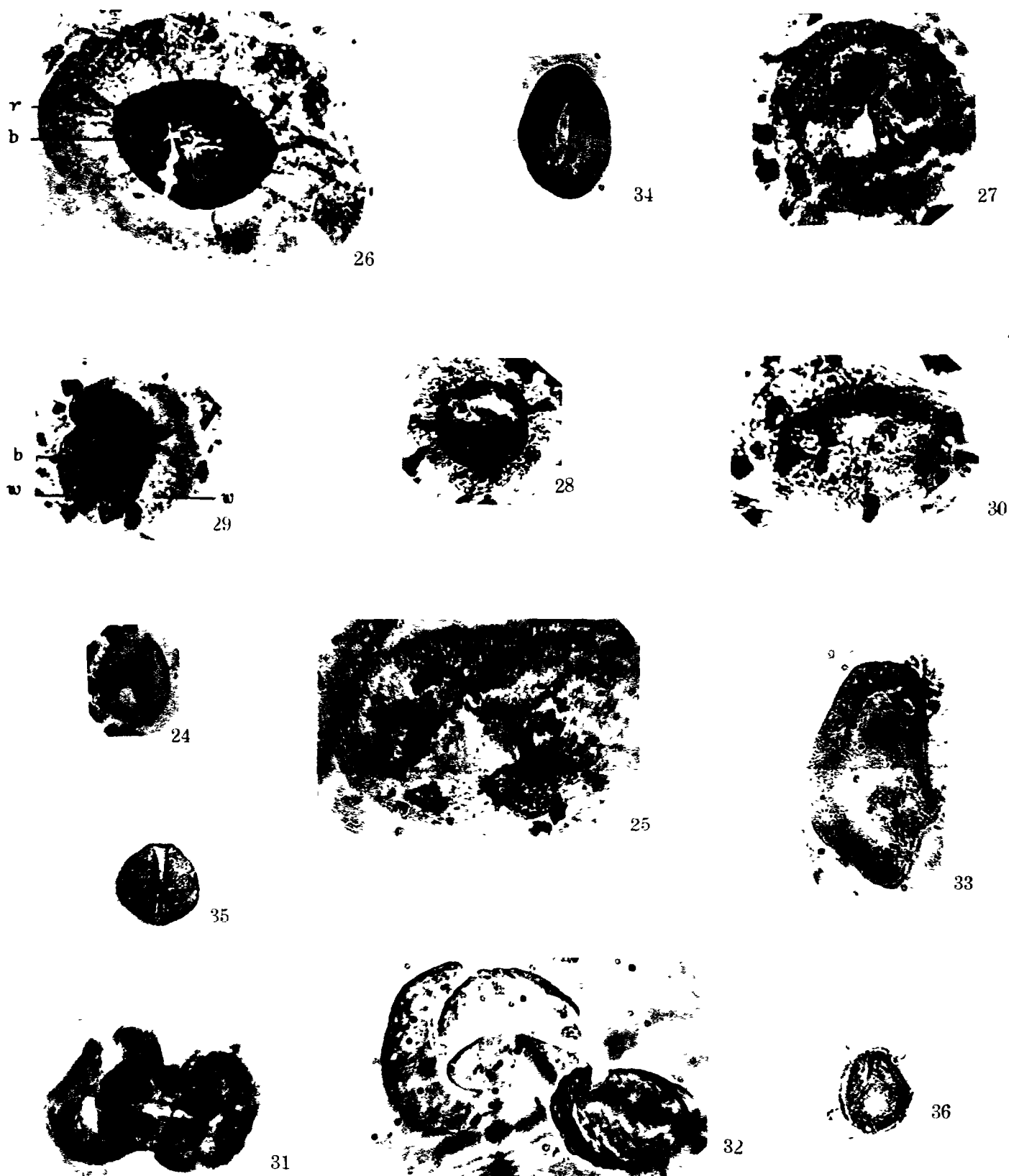


C. Virkki photo.

KATHWAI, SALT RANGE.

Figs. 10—23 : 1½ ft. above the Talchir Boulder Bed.





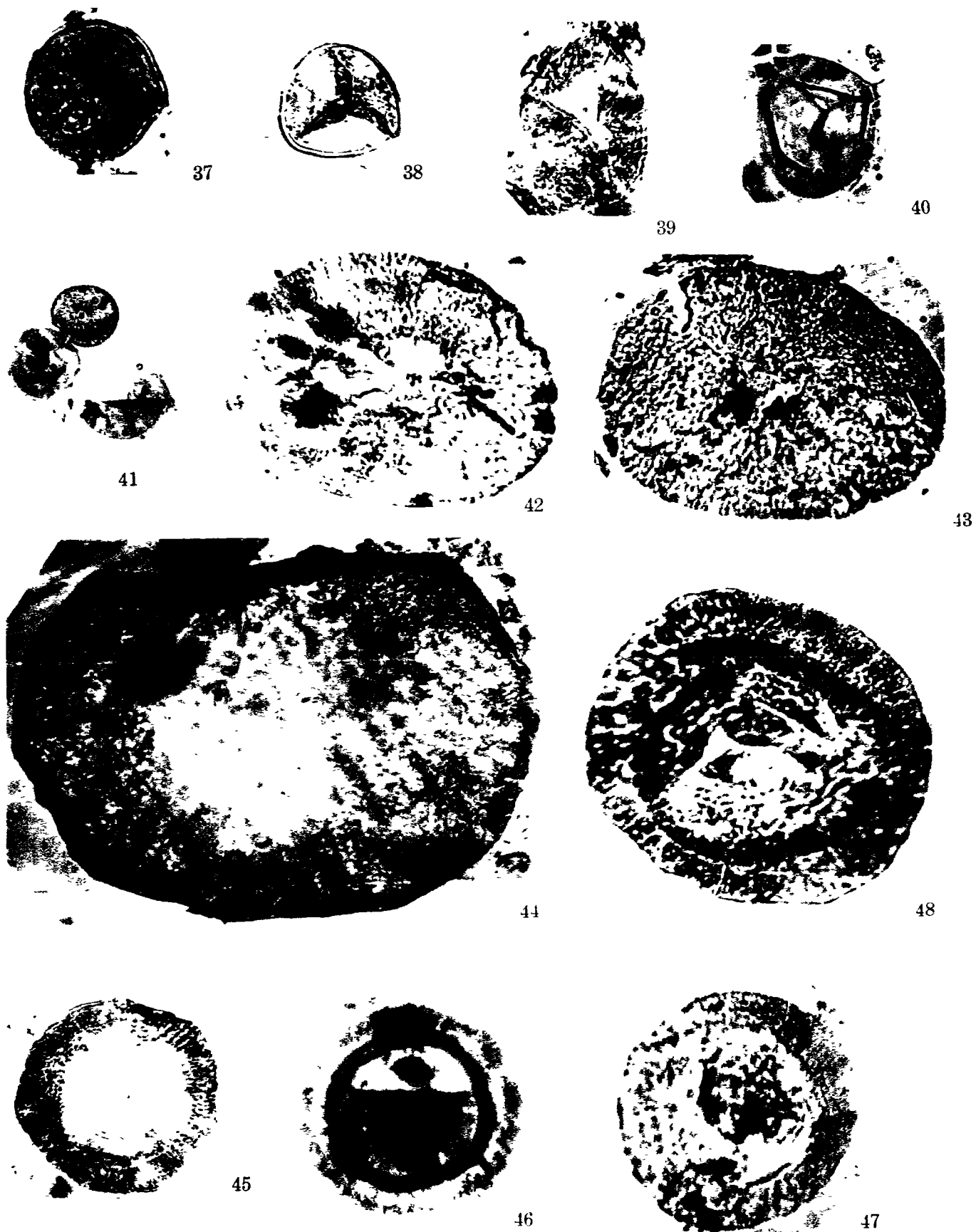
C. Virkki photo

KATHWAI, SALT RANGE.

Figs. 24—30: 4½ ft. above the Talchir Boulder Bed

Figs. 31—36: 20—25 ft. above the Talchir Boulder Bed.





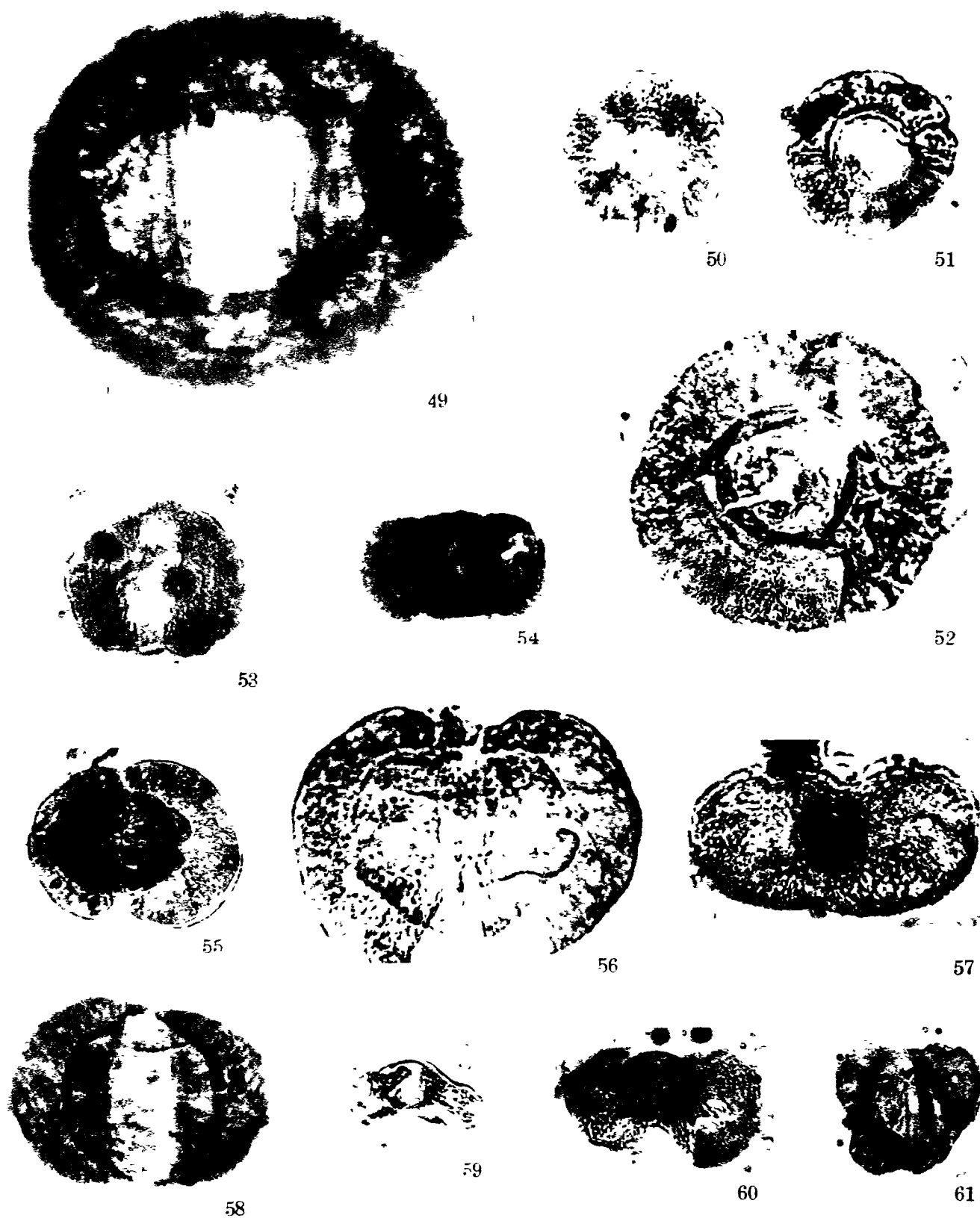
C. Virkki photo.

KATHWAI, SALT RANGE.

Figs. 37-48 . 20-25 ft above the Talchir Boulder Bed.





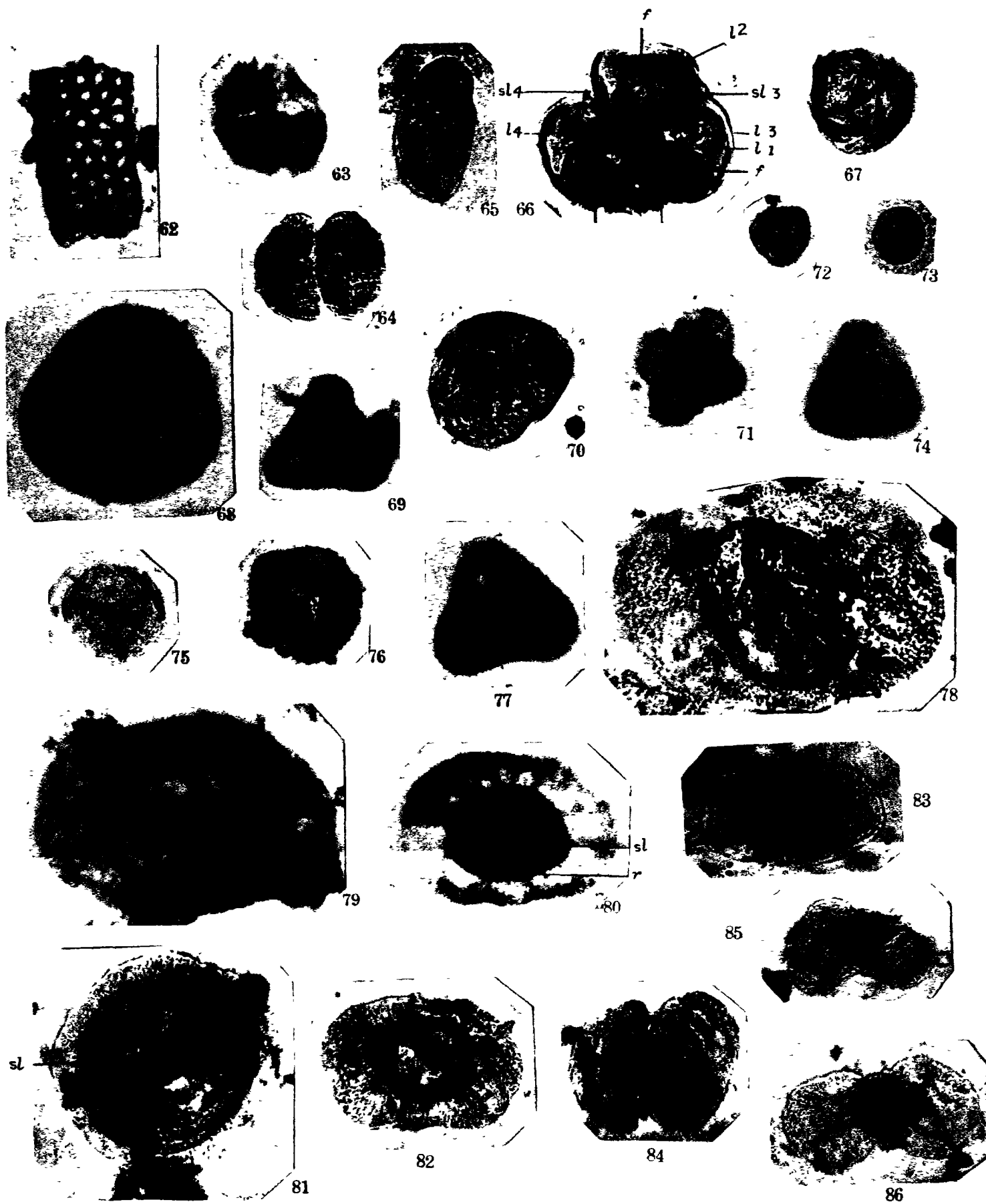


C. Virkki photo.

KATHWAI, SALT RANGE

Figs. 49—61 20—25 ft. above the Talchir Boulder Bed.



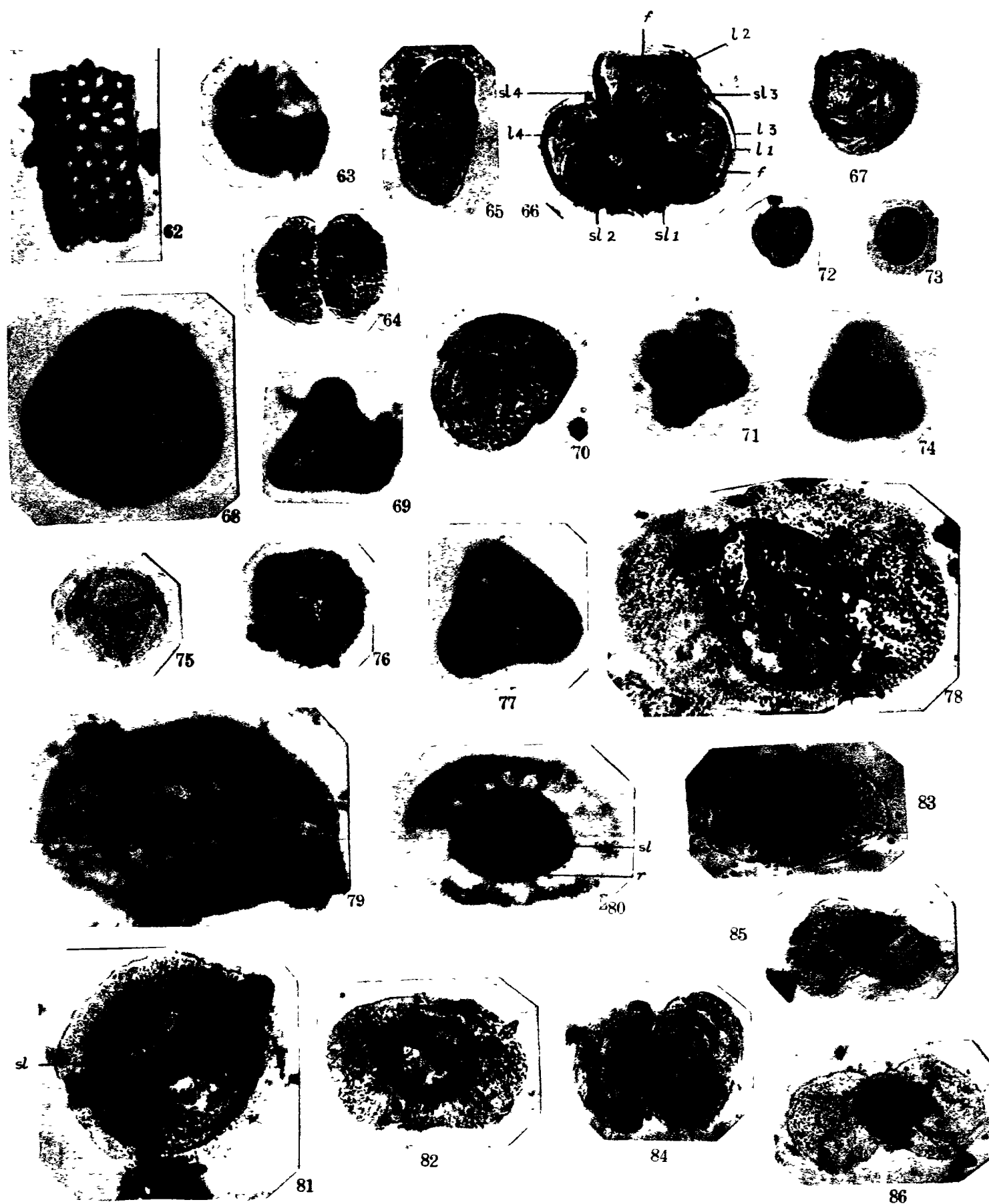


C. Virkki photo.

WARCHHA, SALT RANGE

Figs. 62-86. Just below the Middle Productus Limestone



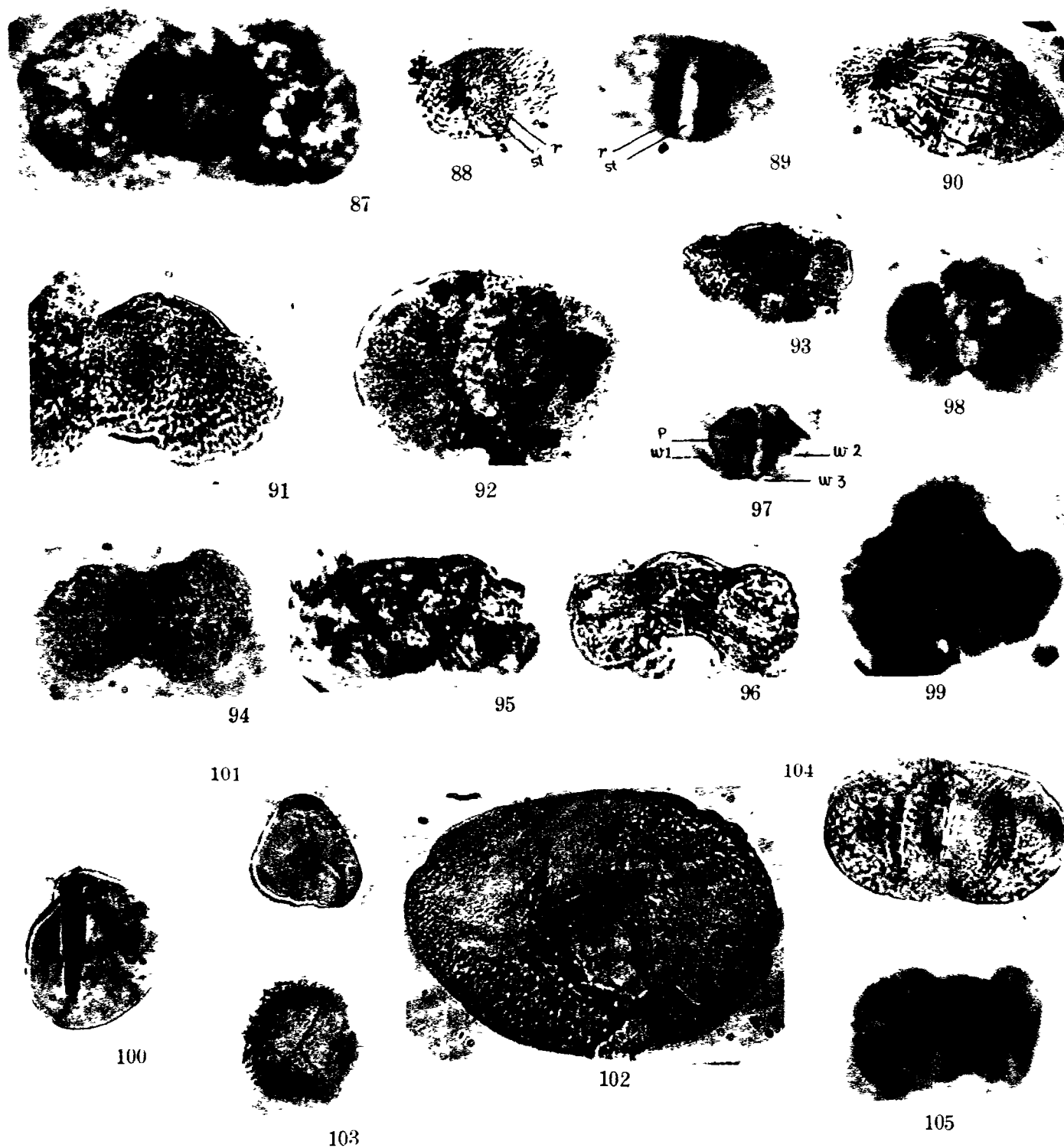


C. Virkki photo.

WARCHHA, SALT RANGE

Figs. 62—86. Just below the Middle Productus Limestone





C. Virkki photo

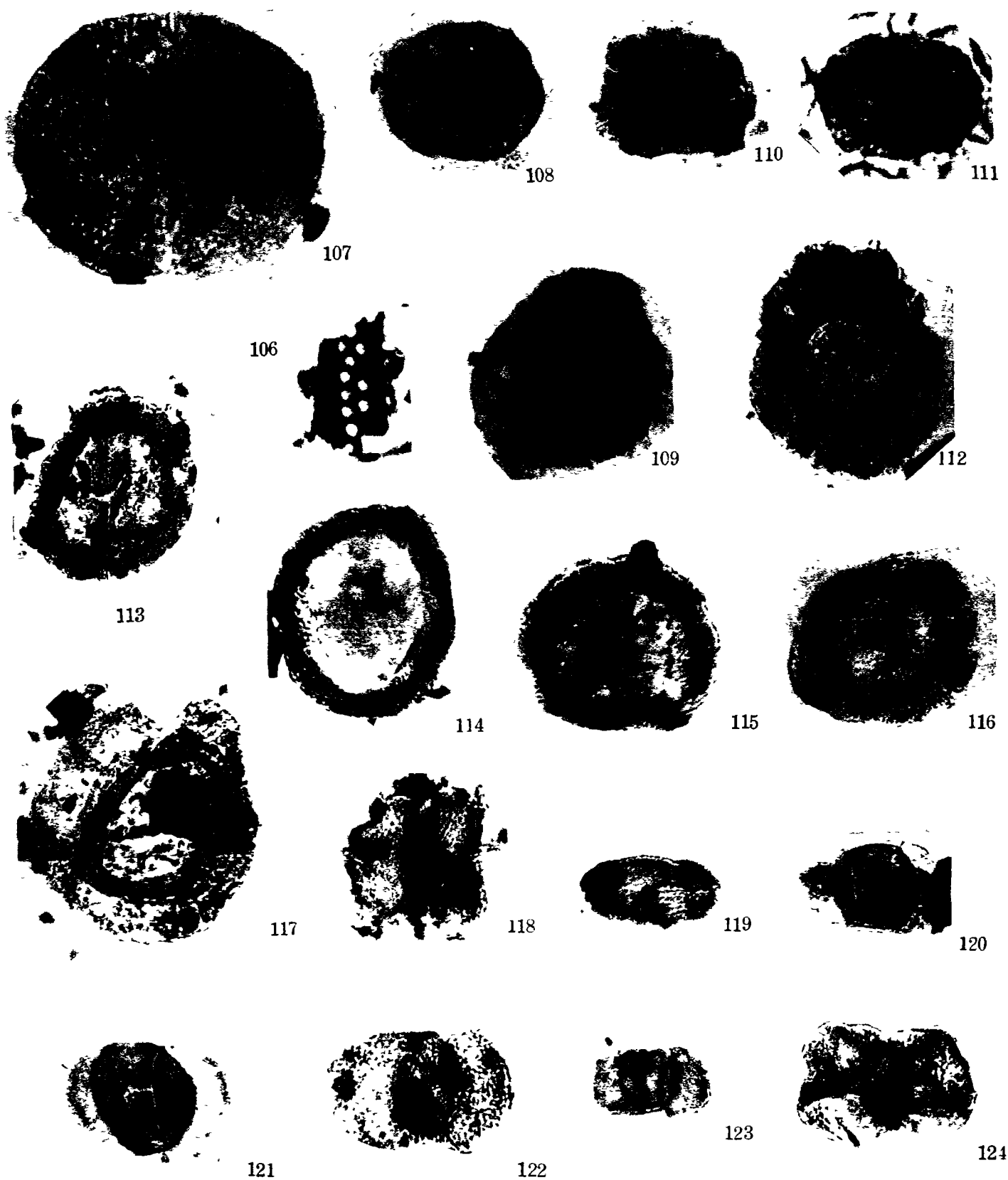
WARCHHA AND JHALLEWALI, SALT RANGE.

Figs. 87—99. Warchha, just below the Middle Productus Limestone

Figs. 100—105: Jhallelwali, just below the Middle Productus Limestone







C. Virkki photo.

DALTONGUNJ COALFIELD, BEHAR.

Figs. 106—124. Lower Barakar (Lower Gondwana.)





125



127

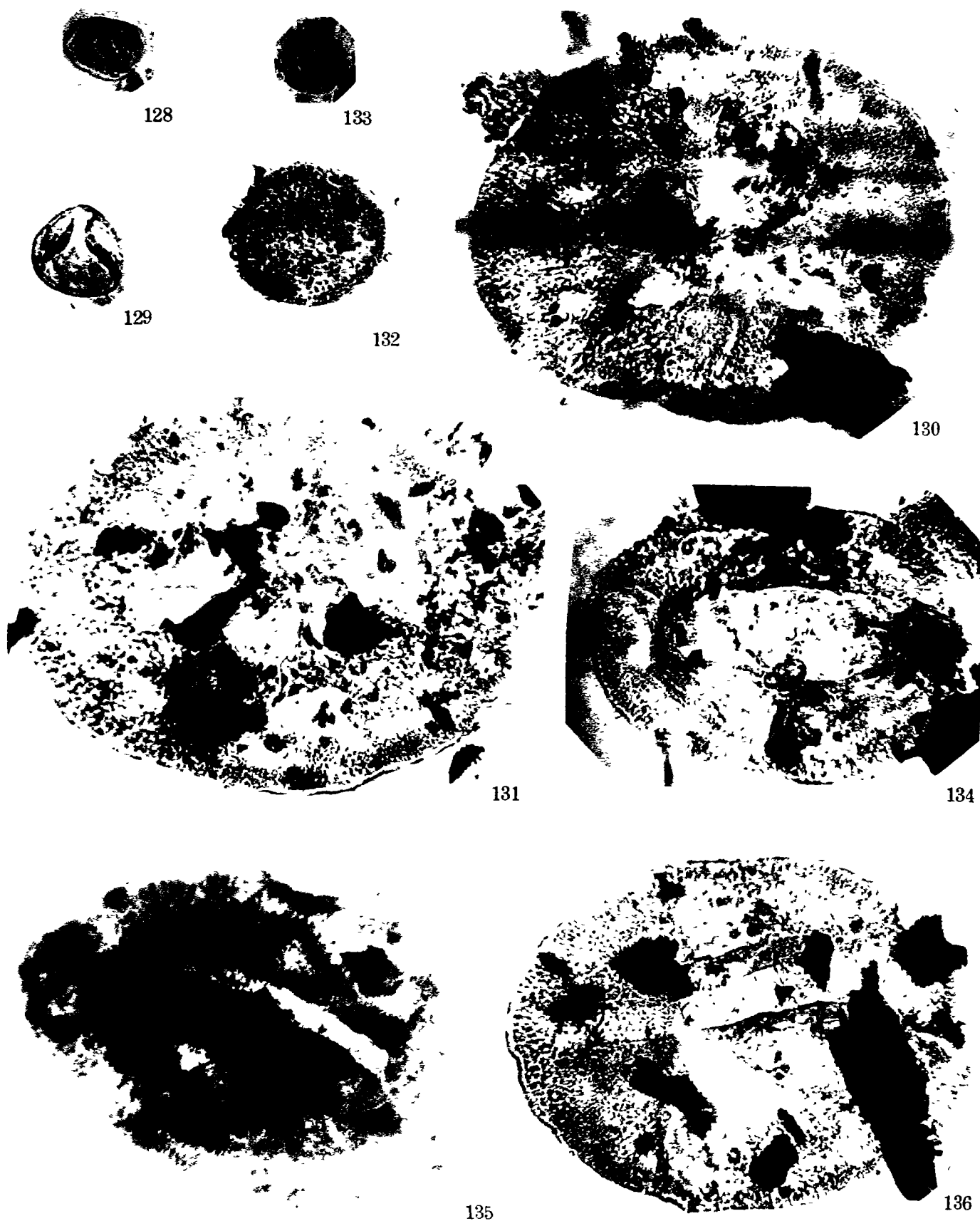


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C. Virkki photo.

Figs. 125—127 Palı Beds, Rewa.



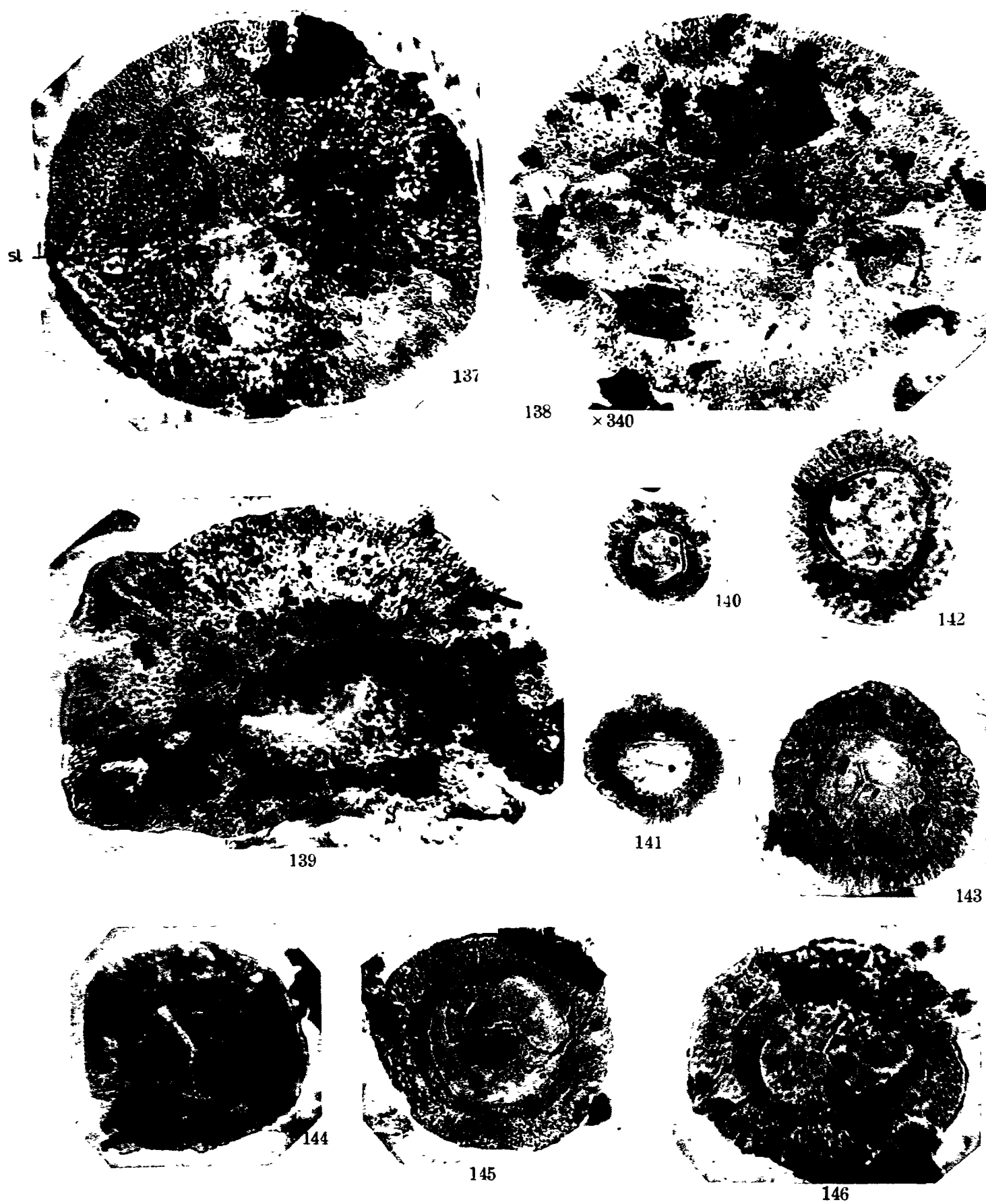


× 400

C. Virkki photo

Figs 128-136 · Pali Beds, Rewa.



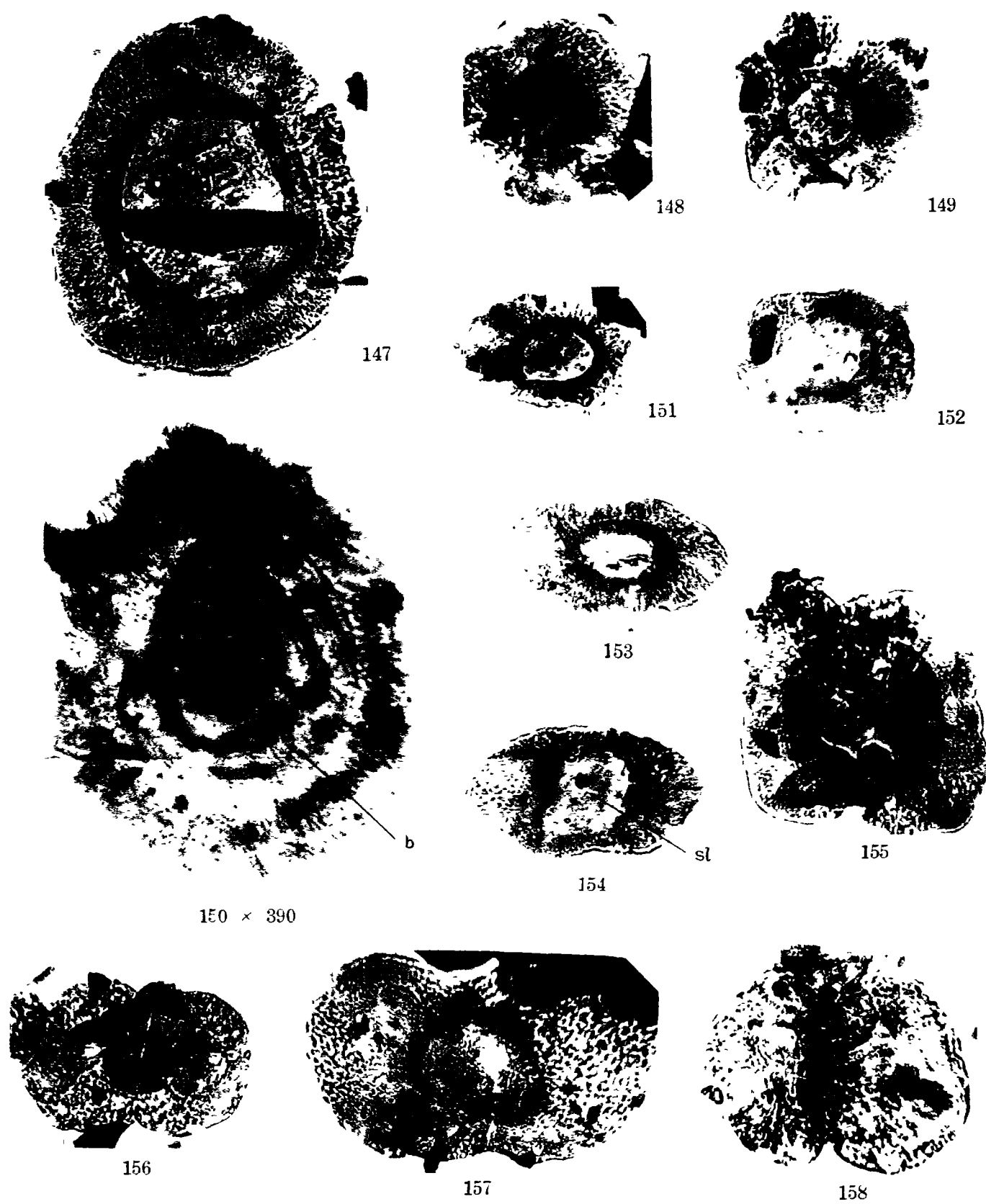


C. Virkki photo.

Figs. 137-146 Pali Beds, Rewa.



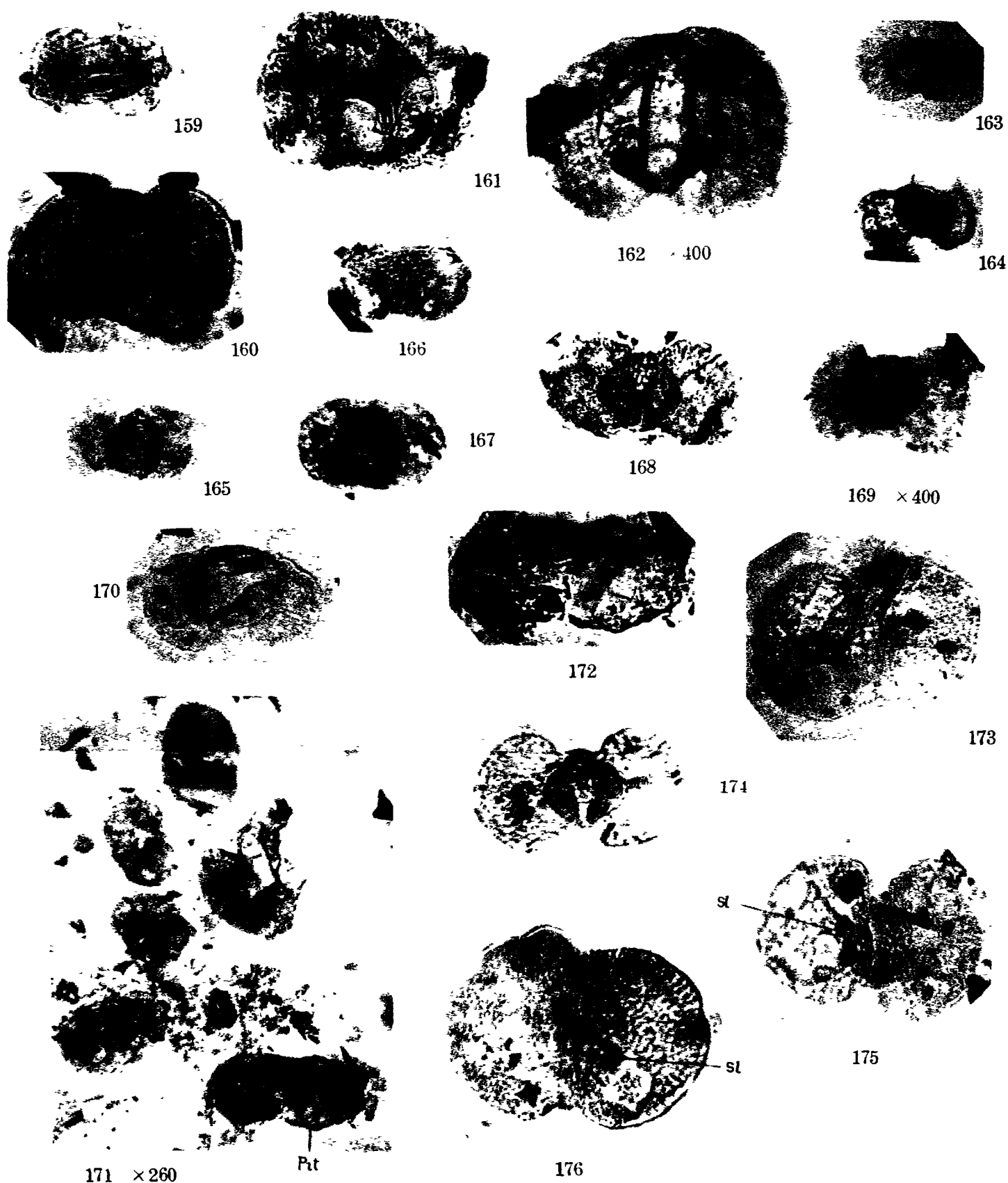




C. Virkki photo

Figs 147-158. Pali Beds, Rewa.





C. Virkki photo.

Figs. 159—176 : Pali Beds, Rewa.





177



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179



187



185



186



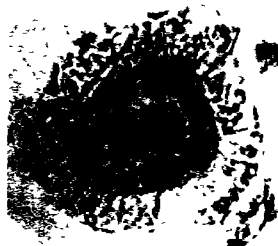
188 × 70



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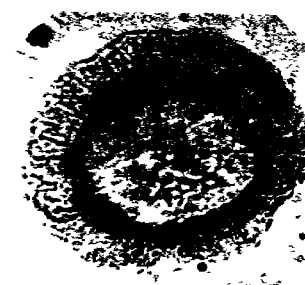
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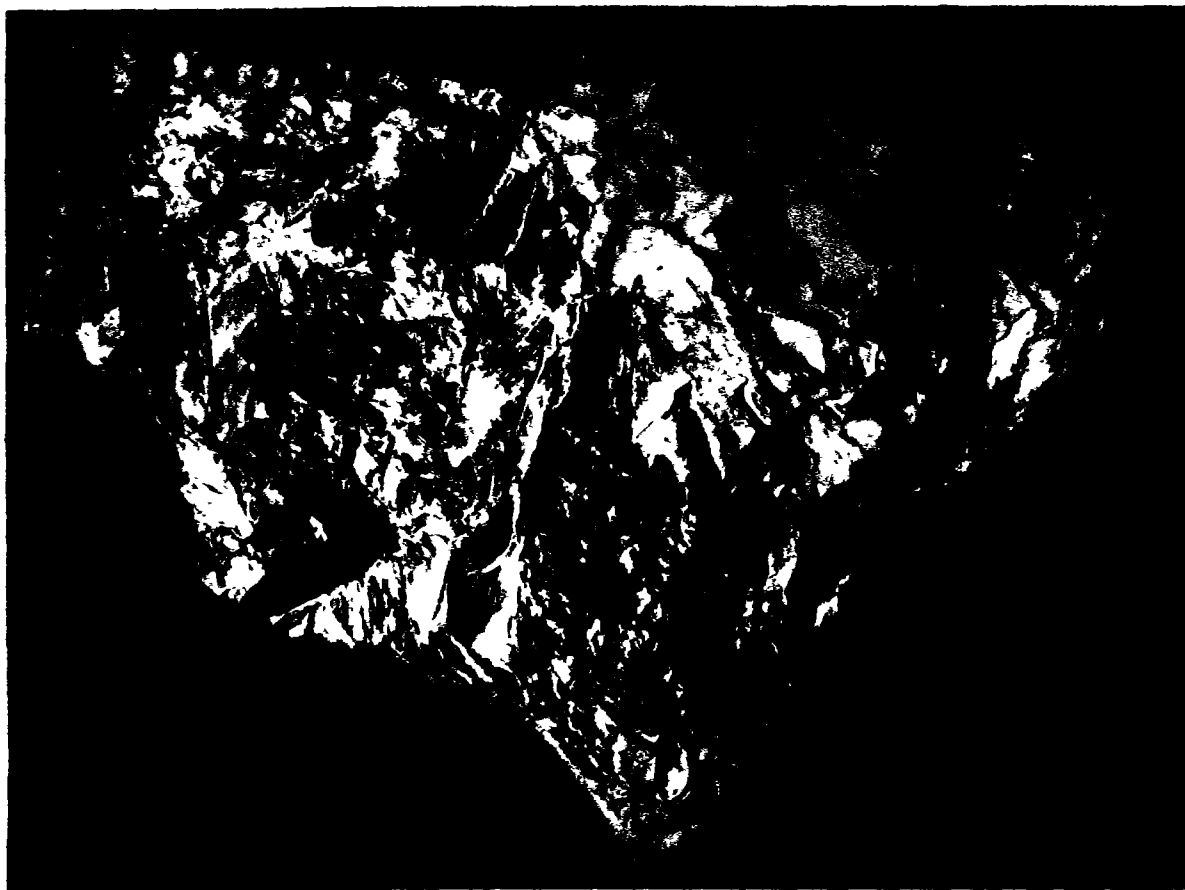


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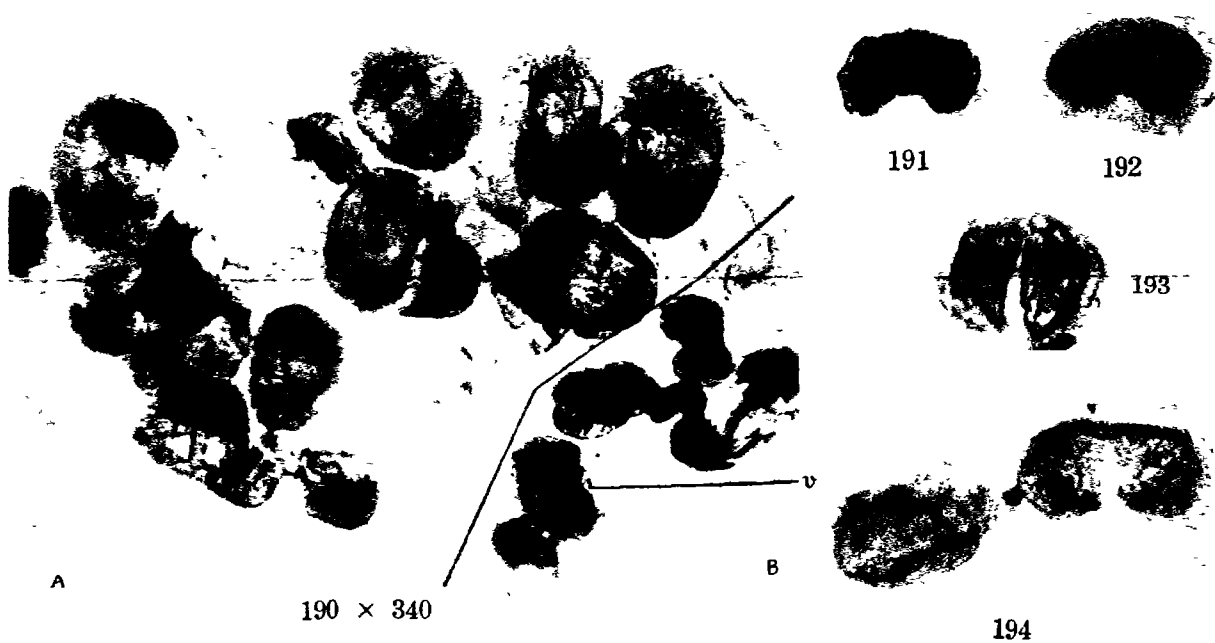
C. Virkki photo.

Figs. 177—188. Bacchus Marsh Tillite, Victoria





189



C. Virkki photo.

Figs. 189-194: Newcastle, New South Wales.





## STUDIES ON THE PHOTOCHEMICAL ACTION IN PLANTS.

### V. EFFECT OF LIGHT ON THE RESPIRATION OF GLUCOSE-INJECTED LEAVES OF *EUGENIA JAMBOLANA*.

BY SHRI RANJAN

Professor of Botany, University of Allahabad.

(Received 20 June 1945).

#### ABSTRACT.

Starved excised leaves of *Eugenia jambolana* were injected with different concentrations of sugar and their respiration rate found out, by the Pettenkofer method, in light.

Injection of sugar immediately effected a rise in  $\text{CO}_2$  evolution in the control experiments kept in dark. The respiration came down to normal in about 4 to 5 hours.

Injected leaves exposed to light showed considerable photosynthesis during exposure, and when brought back to darkness a very marked rise in respiration was noticed.

The respiration rate in dark following exposure to light continued to be markedly higher, for 5 to 6 hours, than the respiration rate of controls, thus showing that light has a positive effect on the respiration rate which, however, is not evident during exposure, due to photosynthesis.

It is argued that the effect of light on respiration is to increase the active hexoses which in their turn cause the respiratory rate to increase. There is, however, an optimal pitch, beyond which the respiration rate cannot go. Thus, even when sugar is injected the respiration rate in light cannot go beyond this pitch. In darkness, the injection of sugars also temporarily increases the active hexoses, whereby respiration increases to this high optimal pitch. There is this difference that, whereas in light the optimal pitch is maintained throughout the light period, in darkness this pitch can only be for a very short duration, due to the rapid conversion of the extra hexose introduced to form reserves.

In a previous paper of this series (Ranjan 1940) it was shown that light increases the rate of respiration of *Pistia* shoots and of yellow *Croton* leaves. It was suggested that there was a distinct photochemical stage in respiration in light. In another paper (Ranjan and Saksena 1940) similar results were obtained with flowers of *Nerium* and *Bougainvillea* which showed markedly increased respiration in light followed by an after-effect of several hours' duration. In the present paper an attempt has been made to study the effect of light on green leaves after injecting them with different concentrations of glucose.

#### MATERIALS AND METHODS

Young and healthy green leaves of *Eugenia jambolana* were selected and put in dark into brass plant chambers, the petioles dipping in a few c.c. of distilled water, in an electric incubator maintained at  $30^\circ\text{C} \pm \frac{1}{2}^\circ\text{C}$ . A current of  $\text{CO}_2$  free air was drawn through these chambers, though no record was kept

of the  $\text{CO}_2$  evolution for the first 22 hours. After this period, when the respiration came down to the steady low level, hourly estimation of the  $\text{CO}_2$  evolution by the leaves was begun using Blackman's air current commutator and Pettenkofer's tubes for absorption of  $\text{CO}_2$  by baryta water. After 2 to 4 hours the leaves were taken out and injected with different concentrations of glucose solution (in one case with 2% glucose and Knop's solution) and immediately put back into leaf chambers in the incubator. One set was exposed to light from a 1000 Watts Osram electric bulb placed at a distance of about 12 inches, the light having to pass through a glass jar 5" broad filled with water which was kept changing by the flow of fresh water through inlet and outlet tubes. The heat rays issuing from the lamp were thus effectively cut off. The other set used as a control was kept in dark as before. The experimental plant chamber was provided with a glass window for the purpose. For each experiment two pairs of opposite leaves were used, one from each pair being used for the experiment and the other for control. After a period of four hours of exposure the light was switched off and the respiration in dark recorded for another 5 to 6 hours.

#### EXPERIMENTAL RESULTS AND DISCUSSION.

##### *Effect of injection of glucose solutions in dark.*

The results obtained after injection with 1%, 2%, 4%, 8%, 12% glucose and 2% glucose+Knop's solution are graphically represented in figs. 1, 2, 3, 4, 5 and 6 respectively. As the recording of the respiration rate starts after starvation of 22 hours, it is seen that the  $\text{CO}_2$  evolution reaches a steady phase where recording begins, and both the control and experimental sets have nearly the same respiration rate until they are injected with glucose solutions.

The effect of the injections of different concentrations of glucose solution can be studied from the figures (dotted lines) representing the control sets. On injection most of the respiring cells of the leaves come in contact with the solution filling the intercellular space; and glucose begins to diffuse into the cells and reaches the metabolic centres. Such injections are likely to start anaerobic respiration. But it has been shown elsewhere that enough oxygen enters the leaves for complete aerobic respiration. Glucose after entry may either be respired off immediately or be condensed into higher forms of carbohydrates or be transformed into other substance. It is possible that all such reactions go on simultaneously within the cells. Soon after injections, however, there is a sudden increase in the respirable substrate in the cells and

as a consequence the respiration rate rises as shown in figures representing the results with 1%, 2%, 4% and 5% glucose solutions. However, the high respiration rate is not maintained but it gradually climbs down to the normal rates in about 4 hours, owing to the depletion of the extra respirable material by rapid condensation or transformation to other substances.

With 12% glucose (Fig. 5), however, the respiration rate rises only slightly evidently due to the complexities of high external concentrations. The respiration rate in this case continues to keep high till the end of the experimental period showing that the penetration of the glucose is a protracted process in this case.

On the whole these results correspond with those obtained by the author at Cambridge (M.Sc. Thesis) with the leaves of cherry laurel.

#### *Influence of Light.*

On exposure to light, the  $\text{CO}_2$  emissions in the Pettenkofer tubes show an immediate fall, and remain at low level until light is switched off. This is evidently due to the simultaneous reduction of carbon dioxide, evolved in respiration, during photosynthesis. It is, however, to be noted that the  $\text{CO}_2$  emission is not altogether stopped in light and part of the  $\text{CO}_2$  formed escapes out.

On removal of light, the respiratory  $\text{CO}_2$ , now no longer being photosynthesized, comes out and the resultant curve as a consequence shows a rapid rise which is followed by a continuous fall. It was shown in a previous paper (1941) that this fall is to be interpreted as a continued influence of light even after it is removed, called by the author 'the after effect of light'.

The falling respiration curve in the experimental set keeps higher than that of the control set, for 5 to 7 hours, after zero hour of darkness. From the respiration rate at the zero hour of darkness, i.e., at the moment of removal of light one can infer the true respiration rate in light. The fact that it is higher than that of leaves kept throughout in dark shows that light considerably increased the  $\text{CO}_2$  evolution during exposure to light but it was masked by the  $\text{CO}_2$  intake by photosynthesis. That the increased after effect of light is not due to the increase of the substrate during photosynthesis is evident from the fact that in spite of the introduction of extra glucose by injection in both the sets, the respiration rate in control reaches back to the normal much sooner than in the experimental sets. It is therefore to be presumed that glucose introduced by injection is soon built back into reserves as pointed out above

and is not available as a direct respiratory substrate. Thus there is no reason for the respiration rate to be maintained at high level after the brief period of adjustment when reserves are built up; for the little amount of glucose formed during photosynthesis will also naturally be transformed into reserves and thus become unavailable for respiration.

By tracing the smoothed out falling curve backwards, the pitch of  $\text{CO}_2$  evolution in light can be derived at the zero hour of darkness. This has been done in Figs. 1 and 2 and shown by dot and dash curves. In Fig. 2 the respiration, on injection, at the zero hour of injection, in the control set, is also similarly shown by (A).

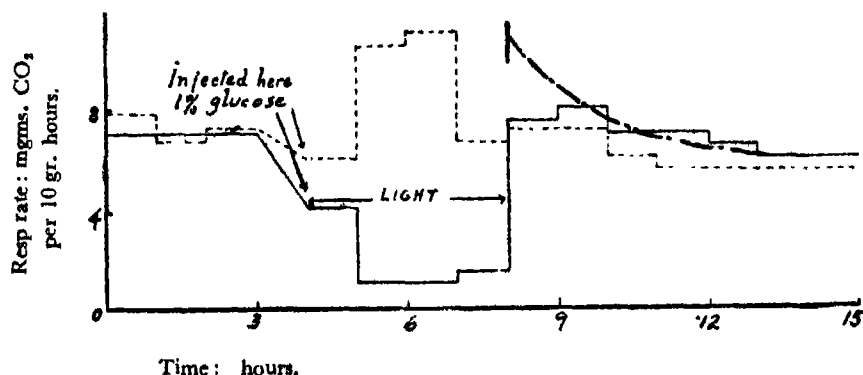


Fig. 1.

..... Control set.

———— Experimental set.

Thus with 1% glucose injection the respiration rate at the moment of removal of light is seen to be 10.5 mgms.  $\text{CO}_2$  per hour. The respiration with 2% glucose injection (Fig. 2) also reached nearly the same level. It is thus evident that the respiration rate at the moment of removal of light is not much affected by the percentage of glucose at lower concentrations. It has not been possible to find similar respiratory values at the zero hour of darkness, with other concentrations of glucose, as the after effect of light does not show the characteristic falling curve.

From the falling curve of respiration, after removal of light, it is evident that the respiration rate in light is high and on removal of light the rate gradually falls down to the "dark level." The "light level" of respiration, i.e., the level of true respiration in light can then be constructed by tracing

this high respiration rate at the zero hour of darkness backwards during the period of exposure to light. This is done in Fig. 2 and shown by arrow-heads.

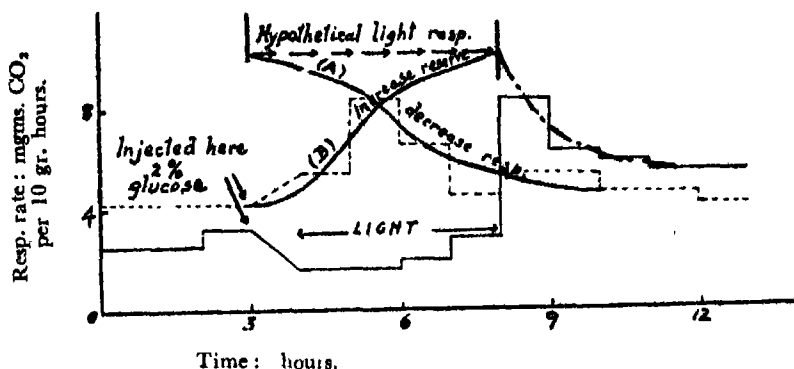


Fig. 2.

..... Control set.

———— Experimental set.

This is, thus, the true level of respiration in light which is, however, masked by the photosynthetic processes going on during the period. This derived unmasked respiration level is higher than the respiration level in dark due to augmentation of respiration by light. Recently Föchler (1938) also obtained higher respiration in plants exposed to light and confirmed the author's previous observations that there is an acceleration of respiration for many hours even after transferring the tissues to the dark.

In experiment 2 the control set shows after a short rise a falling curve after injection with glucose. This curve of respiration is the resultant of two curves, viz. (i) increased respiration due to increase in active hexoses marked (A) in Fig. 2 and (ii) decrease in the respiration rate due to the rapid depletion in the active hexoses and a proportionate increase of the reserve marked (B). By interpolation of the curve (A) backwards, the highest respiration on injection is derived. This attains the same level as the experimental set on removal of light. The increased substrate by injection and the exposure to light both seem to have almost the same effect on the respiration rate—increasing the quantity of the active hexoses within the cells.

In the control set an injection of glucose increases temporarily the concentration of this substrate within the cells where it is partly converted to the active hexoses and partly to the reserve substances until the the concentration again falls to the original level. The sudden increase in the active hexoses is

responsible for the increased output of carbon dioxide and as a consequence the accompanied rapid consumption of the active hexoses brings down, soon after, the high respiratory level.

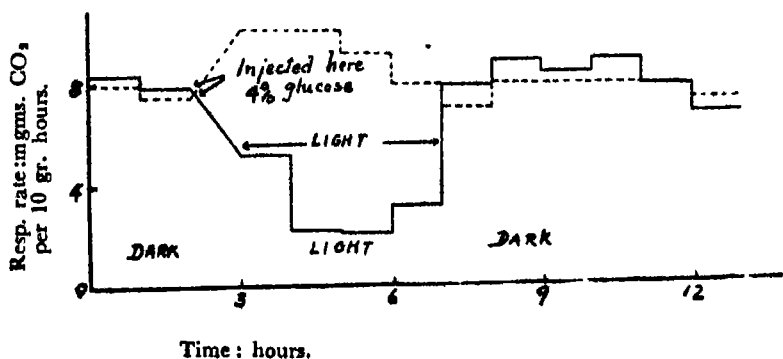


Fig. 3.

..... Control set.

———— Experimental set.

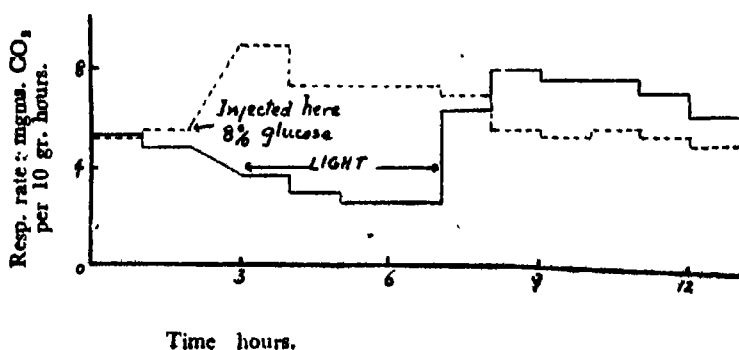


Fig. 4.

..... Control set.

———— Experimental set.

In a previous paper (Ranjan 1941) it was suggested that light also increases the active hexoses not by inducing an increase of hexoses in the cells but by converting a part of hexoses into the more active form by absorbing the light energy. Thus here, too, an effect similar to the glucose injected effect, is manifested in the production of CO<sub>2</sub>. But this high concentration of active hexoses can only be maintained as long as the leaves are exposed to

light and on removal of light the concentration gradually falls to the original level. The similarity in behaviour of  $\text{CO}_2$  production can be ascribed to the increased production of active hexoses induced by different agencies.

One other point seems interesting. Temperature has a profound effect on the rate of respiration and it was shown elsewhere (Ranjan 1941) that light has greatest effect at  $27^\circ$  to  $30^\circ\text{C}$  on the respiration rate. At higher temperatures light did not induce a greater respiration rate as the hexoses were already in an active form. It seems, therefore, that with a definite concentration of the hexoses in the cells, there is a pitch of concentration of active hexoses that can be induced, and the exposure to light or high temperature cannot augment the production of the active hexoses beyond this limit which is probably, at this level, controlled by some internal factors such as enzymes. The  $\text{CO}_2$  production, being controlled by active hexoses can thus be increased to a definite pitch and not beyond. This pitch seems to have been reached by both the experimental sets in Figs. 1 and 2 and the control sets and therefore the  $\text{CO}_2$  production curves when drawn backwards reach the same level. It is interesting to find that an experiment with *Eugenia* leaves similar results were achieved (Ranjan 1941; Fig. 7 page 193).

The experiment with 12% glucose (Fig. 5) is in a way peculiar. It has been mentioned that owing to the very high osmotic pressure on the outside

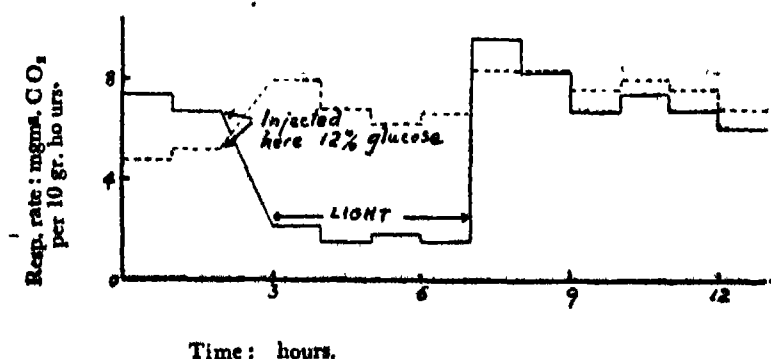


Fig. 5.

..... Control set.

———— Experimental set.

the penetration of sugar within the cells is slow. The building up of reserves is also slowed down and it results in a continuous supply of respirable substrate for a much longer time and hence the respiration rate in the control set continued



at a high rate for a considerably long time and did not reach the original level even up to the end of the experimental period. At the zero hour of darkness the respiration rate in the experimental set is fairly high as in the control set, due to large substrates available in an active form and the respiration curve, therefore, does not show the effect of light as clearly as in other experiments.

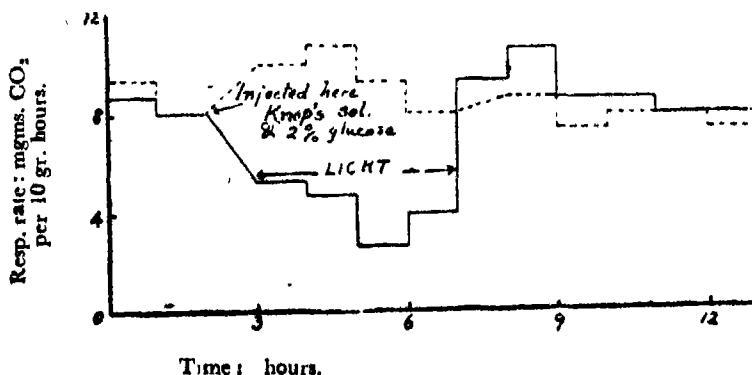


Fig. 6.

..... Control set.

———— Experimental set.

In the last experiment (Fig. 6) 2% glucose in Knop's solution was injected in both the control and the experimental sets. The result is essentially the same as obtained with injecting glucose alone and Knop's solution seems to have no particular influence.

The author wishes to thank the Allahabad University for meeting the expenses of publication of this paper.

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PROCEEDINGS  
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NATIONAL ACADEMY OF SCIENCES  
INDIA  
1945

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*With an Obituary Note on the author by B. Sahni*

ALLAHABAD  
PUBLISHED BY THE COUNCIL  
Price Rs. 2 (India); Rs. 2/8 (Abroad)



SILICIFIED PLANT-REMAINS FROM THE  
RAJMAHAL SERIES OF INDIA

By

THE LATE B. P. SRIVASTAVA, M.Sc.,  
Research Fellow, University of Lucknow.  
Sometime Professor of Biology, M. T. B. College, Surat.

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*With 10 Plates*

---

*With an Obituary Note on the Author*

By

B. SAHNI, Sc.D., F.R.S.



B. P. SRIVASTAVA,  
1904—1938.

#### OBITUARY NOTE ON THE AUTHOR.

Baleshwar Prasad Srivastava was born in 1904, son of the late Mr. Babunandan Lal Srivastava, a retired postmaster at Panna, Central India. He received his early education at the Queen's A.V. High School, Lucknow and at the Agra College. In August, 1923 he entered the University of Lucknow and in 1925, after taking his B.Sc., joined my postgraduate class, obtaining an M.Sc. degree in 1927. Here he soon developed an interest in botany which grew into a keen desire for original work. But the lure of a research career had to yield to the necessity of making a living. For broken periods from 1927 until his premature death (from tuberculosis) in 1938 he held the post of professor of biology at the M.T.B. College, Surat. There he did valuable work, for he appreciably improved the equipment of his department, widened the outlook of his students and generally raised the standard of teaching. During this period Srivastava met the Danish algologist F. Boergesen who has made valuable contributions to the marine algal and angiosperm flora of the Indian sea-coast. In assisting Boergesen in the field Srivastava acquired a stimulating contact with a distinguished foreign botanist.

For a time Srivastava worked as demonstrator in Botany at Lucknow. It was during this period that his interest in palaeobotanical research was created. Silicified material of the Rajmahal flora had recently been discovered by G. V. Hobson of the Geological Survey of India in the Amrapara district of Behar, and subsequent excursion parties from Lucknow had brought back a quantity of further specimens from Nipania. This growing collection urgently needed attention, for it contained petrifications of a classical Jurassic flora until then known almost exclusively from impressions. The aim was firstly to describe the individual specimens and then to correlate them as far as possible with each other and thus to reconstruct what could be visualised of the parent plants.

This was clearly a big task, so I decided to invite the co-operation of B.P. Srivastava, A. R. Rao and K. M. Gupta, with myself serving as a co-ordinating link and at the same time taking a hand in the descriptive work. Later K. Jacob, R. V. Sitholey and P. N. Ganju joined the Jurassic team, for meanwhile further material had come in, collected in the Salt Range by E. R. Gee, in Afghan-Turkistan by C. S. Fox, and in the Rajmahal Hills by our own parties from Lucknow. This included impressions and incrustations as well as petrifications.



Srivastava's share in the work turned out to be most interesting, as the following paper clearly shows. Although he did not live to complete the allotted work he had the satisfaction to know the important contribution that he had made to Jurassic palaeobotany. He continued to work here during gaps in his long illness, of which the serious nature was not suspected until, alas, it was too late. He died at Devas (Jr.) on the 21st December, 1938. As he had found it difficult to prolong his leave he had taken the entire material with him to Surat, where he worked at it whenever he could, occasionally visiting Lucknow for consultation. Much of the material had been collected by himself, and he also prepared many of the thin sections with his own hands at Lucknow, bringing out several obscure structural features by staining the slices with safranin, gentian violet or aniline blue.

The material allotted to Srivastava for description was extremely rich in leaves of *Taeniopteris spatulata* McCl. which were associated with several kinds of stems and at least three distinct genera of gymnospermous seed-bearing cones, besides numerous other fragments. Another lot of the same material, equally full of *Taeniopteris*, was entrusted to A. R. Rao, who was to concentrate on the anatomy of these leaves and describe the coniferous remains (*Proc. Ind. Sci. Congr.* 1935 p. 283; 1936 p. 304; 1937 pp. 151-152; *Proc. Nat. Acad. Sci.* 1943, 1944).

Before handing over this material I had only made some preliminary observations. *Williamsonia Sewardiana* and *Homoxylon rajmahalense* had already been described in full. A lax female cone, presumably coniferous, was now briefly described and named *Conites Hobsoni* after the discoverer of the important plant-bearing locality at Nipania (*Proc. Ind. Sci. Congr.* 1932 pp. 322-323). In the midrib and petioles of *Taeniopteris spatulata* I had found a row of mesarch (diploxylic) vascular bundles of the *Cycas* type (*Pro. Ind. Sci. Congr.* 1932 p. 322; *Ibid.*, 1938 p. 152 fig. 5). A similar row of bundles was also seen in the rhomboid leaf cushions on some small cylindrical shoots of cycadean aspect frequently found associated with these leaves, and I suspected (from the number of bundles in the midrib and the size of the petiole base) that *T. spatulata* belonged to the same plant as these shoots.

During his careful investigation Srivastava was not only soon able to confirm this suspicion but he made several other interesting discoveries among the associated plant remains, which are described and figured in the paper now being published below. These and other observations were presented before the

6th International Botanical Congress held at Amsterdam in 1935 (*Proceedings. Vol. II pp.* 248-249), when a summary was given of the work then in progress on the Rajmahal flora, and thin sections, many of them stained by Srivastava, were exhibited.

The full significance of Srivastava's work will only be apparent after his illustrated paper has been published: hitherto only a few selected figures and brief diagnostic descriptions, drawn up by myself on the basis of the notes left by him, have appeared (see under *Srivastava, Palaeobot. in India V, Proc. Nat. Acad. Sci.* 1944 *pp.* 73-76, *figs.* 10-14). Mention should also be made of two preliminary papers by him published only in abstract form, without figures. These are reproduced below as they may not be accessible to readers abroad.

With his methodical habits of work Srivastava had carefully numbered nearly all his sections and the blocks from which they were cut. With only a few exceptions it has thus been possible to correlate his descriptions and figures with the original material. Fortunately his manuscript (so far as it had been written up) was also left in a fairly advanced stage of correction; but there are some important gaps, and a few points of detail remain in doubt. The author's younger brother, Mr. D. S. Srivastava, M.Sc., kindly arranged for the return to Lucknow of all the MSS., notes, sections and uncut blocks of material left at Surat. To him I am indebted for some personal details of the Author's early career.

In preparing the work of my late pupil for publication I have received much valued help from Dr. A. R. Rao and Dr. R. V. Sitholey, for which I am very grateful. This task has been for us a labour of love. It has involved a considerable re-arrangement of the text and illustrations, for Srivastava had originally intended to publish a separate paper on each of the genera he was describing. The explanations of the figures have to a large extent been written anew, and the few original explanations available have been checked as far as possible with the help of notes left by the Author. But, except in so far as this was incidental to the rearrangement and editing of the material, the original language of the text has been left practically unaltered.

B. SAHNI.

Lucknow, 21st February, 1946.

1. On some silicified plant-remains from the Rajmahal Series of India.  
(*Proc. 22nd Ind. Sci. Congr. Calcutta, 1935 p. 285*).

Numerous fossil impressions have been recorded from this classical area but so far only a few petrified forms have been described, notably by Seward, Bancroft, and Sahni. The locality Nipania, first discovered by Mr. G. V. Hobson of the Indian Geological Survey, has yielded a rich silicified flora, in which several new genera and species have been recognised. The majority of the thin sections have been stained with safranin and gentian violet with very good results.

(i) A stem with *Lycopodium volubile* type of stele, possibly a petrified specimen of *Lycopodites gracilis* (O. and M.)

(ii) Fern rachises (a) with a single C-shaped petiolar bundle, but of a complicated outline, (b) with a single petiolar bundle (? cf. *Gleichenia*) in a rachis with attached pinnae or pinnules.

(iii) *Pentoxylon Sahni* gen. et sp. nov. Stems with usually five steles arranged in a ring; in each stele the centripetal development of the secondary wood far exceeds the centrifugal.

(iv) *Nipanioxylon Gupta* gen. et sp. nov. Stems with usually eight steles arranged round a wide pith, which show equal development of the secondary wood on all sides. Possible leaf traces with numerous bundles are also seen in the cortex.

(v) *Carnoconites* gen. nov. Fructifications with numerous fleshy seeds; stony and outer fleshy layer well developed; nucellus free from integument.

(vi) *Comites* sp. Ovuliferous scales perhaps spirally arranged; one ovule on each scale rather distally attached; nucellus free.

2. Studies on some silicified plant-remains from the Rajmahal Series.  
(*Proc. 24th Ind. Sci. Congr. Hyderabad, 1937, pp. 273-274*).

The study of the following types is based on silicified material, belonging to the Rajmahal series of India, collected from Nipania, Santhal Parganas, Behar. (*Srivastava, Proc. Ind. Sci. Congr., 1935 and Proc. 24th Ind. Sci. Congr. Amsterdam, II, p. 248, 1935*).

**Part I.**—On the anatomy of *Lycosylon indicum* gen. et sp. nov., a stem with *Lycopodium*-like stele.

Stems 1-2 millimeters in diameter. Stelar anatomy *Lycopodium* like, with about twenty protoxylem groups and very suggestive of the *L. volubile* type. Phloem and phloem sheath not preserved. A circular gap (in a cross section) surrounds the stele and this is followed by a band of thick-walled inner cortical cells. Stem decorticated. Outer cortex containing the leaf-traces and the clothing of leaf bases missing.

Longitudinal or oblique sections show scalariform pittings, as in the living genus.

If it is really a *Lycopod*, it is rather strange that the huge lycopods of the Palaeozoic were succeeded in the Jurassic by such diminutive types. The presence of *Lycopodium* has long been suspected in the Mesozoic, but till now all the species known occur as impressions (*Lycopodites*). This specimen after all may be a petrified twig of *Lycopodites gracilis* (O. and M.).

To refer this Jurassic specimen to the genus *Lycopodium*, merely on the strength of its stelar character, may not be advisable. *Asteroxylon*, for example, resembles *Lycopodium* in its stelar characters but its affinities are, as we know, entirely different. In view of this, the specimen under consideration has been referred to a new genus *Lycosylon*.

**Part II.—On *Pentoxylon Sahnii* gen. et sp. nov.**—A new type of gymnospermic stem.

This is one of the commonest plant remains in the silicified flora of Nipania and is characterized by the presence of usually five vascular bundles, arranged in a ring in the ground-tissue.

Each vascular bundle consists of a lenticular mesarch primary portion. At first secondary growth follows equally around each one of these, but soon there is a tendency for a pronounced entripetal development of the secondary elements. Wood compact with well marked growth rings. One to three more or less wedge shaped branch traces alternate with the bundles. Sclerotic nests are present in the ground-tissue.

Protoxylem tracheids have annular and spiral thickenings, while the secondary elements show uniseriate, contiguous, round bordered pits. Summer tracheids of older wood, however, usually show a biseriate, contiguous, alternate pitting. Medullary rays uniseriate, usually 2-7 cells high. A single large pit in the field. Secondary phloem cells have tangentially thickened walls.

Sometimes there are six bundles instead of the usual five. Not infrequently one or a few of the bundles grow larger in size than the rest or may show a pronounced centrifugal growth of the wood.

**Part III.—On *Nipantoxylon Guptai* gen. et sp. nov**

Stems with usually eight vascular bundles having equal secondary growth all round. Pith and cortex wide, 1-3 sets of more or less mesarch collateral traces traverse the cortex. Numerous sclerotic nests found in the cortex and pith. Xylem of the vascular bundles and the traces consists of scalariform tracheids. Radial pits of secondary tracheids uniseriate, circular, contiguous. Medullary rays uniseriate.

Several spherical stem pieces, hardly a few millimeters in diameter (5 mm. to 1 cm.), also show a wide pith, clearly delimited by 'a jacket of cells'. In the cortex are found eight vascular bundles, sometimes less due to fusion, often showing a centrifugal disposition of tracheids.

**Part IV.—*Carnoconites*—a new genus of fleshy ovuliferous cones.**

*Generic diagnosis.*—Strobili bearing several ovules with micropyles pointing outwards. Outer fleshy and stony layer well developed. Nucellus totally free from the integument. Megaspore membrane thick. Nucellar cone projects into the micropyle. Ovular supply terminates below the base of the nucellus. Female prothallus preserved in many cases. Few seeds contain the remains of an embryo.

*Carnoconites* sp. A. Compact cones about 2 cm. × 1 cm., bearing 5 to 6 ovules in each longitudinal row, sometimes very few. Fleshy layer 1-2 mm. broad. Cones borne on long stalks which emanate from a central axis. 3-5 mesarch vascular bundles traverse the stalk. Cone axis shows 5-6 mesarch bundles.

*Carnoconites* sp. B. Lax cones about 3 cm. × 5 cm., with up to twenty ovules in each longitudinal row. Ovules smaller but more numerous in this species. Fleshy layer less developed, though distinct. On comparison with the original specimen, it seems to be the petrified specimen of what is known in impressions as *Strobilites Pascoi* Sahnii.

# SILICIFIED PLANT-REMAINS FROM THE RAJMAHAL SERIES OF INDIA.

By the late B. P. SRIVASTAVA, M.Sc.,

RESEARCH FELLOW, UNIVERSITY OF LUCKNOW.

SOMETIME PROFESSOR OF BIOLOGY, M. T. B. COLLEGE, SURAT.

(With 10 plates).

(Communicated by Prof. B. Sahni, Sc.D., F.R.S.)

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## INTRODUCTION.

The Rajmahal Series, as is well known, forms an important division of the Upper Gondwana system of India, corresponding in age to the Liassic of Europe according to Feistmantel (1877) but probably younger according to more recent workers (*Halle* 1913). It has yielded a store of plant impressions, but the general paucity of petrified material, as is general for the Mesozoic period, has always been a source of keen disappointment to palaeobotanists working on this formation. Occasionally, however, fossil wood or a few stray silicified blocks containing plant remains have been discovered and their structural details worked out, notably by Professor Seward, Dr. Bancroft and Professor Sahni. The structure of *Bucklandia indica* (*Seward* 1917 p. 488), *Homoxylon rajmahalense* (*Sahni* 1932), *Williamsonia Sewardiana* (*Sahni* 1932 a) is now well known.

But it was in the year 1929 that rocks containing plant remains in a comparatively fine state of preservation were discovered *in situ*, by Mr. G. V. Hobson of the Indian Geological Survey, at *Nipania*, a village in the Santal

Pargana District of Behar. A trip to this otherwise totally out of the way place was undertaken by Professor Sahni and his postgraduate students in the year 1930. Collections made on this occasion originally formed the material of the present paper. This was later supplemented by a further collection by the author and Mr. (now Dr.) K. M. Gupta in 1934.

The discovery of mesarch bundles of the *Cycas* type in the midrib of *Taeniopteris spatulata* by Professor Sahni (1932b p. 322; 1938 p. 43 and Fig. 5) and the few new types described here fully justifies the attention these fossils have received\*.

#### MATERIAL AND TECHNIQUE

The material consists of silicified blocks, usually of a portable size. The majority of the blocks were cut by a wire-bow and carborundum powder, but some were later cut by a motor-driven band-saw. One or two sections were cut in London under the supervision of Professor Sahni, when he had taken some of the slides and blocks for demonstration at the Fifth International Botanical Congress, Amsterdam (See Sahni 1935).

Sections, as a rule, have been stained with safranin or gentian violet. The stain in some cases permeates into the interior and the organic remains take up the stains vividly, the matrix remaining unaffected. It was initially at the suggestion of Professor Sahni that the staining of the sections was attempted. Alcoholic safranin, gentian violet, aniline blue, Bismarck brown, erythrosin, Congo red and methyl green were tried. All except Bismarck brown gave more or less satisfactory results, but the sections were always brilliantly stained with safranin and gentian violet. The value of this rather unique suggestion of Professor Sahni will be apparent to those who see the amazing beauty of some of the stained sections. Staining has brought out some important structural details, which would have certainly been otherwise missed or overlooked. For ordinary staining gentian violet has been found to be the best. Staining for even half a minute is sufficient, but such a stain fades off soon. If, however, a section is stained for a couple of minutes or more, the stain is more lasting. Double this time or even a longer period is necessary while staining with safranin. For slightly weathered specimens, especially sections of fossil wood, which are slightly porous, alcoholic safranin gives the most lasting result, safranin being also a useful stain for photographic work. It is always advisable to keep the stained sections in the dark.

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\*A fully illustrated account of the leaves known as *Taeniopteris spatulata* has recently been published by A. R. Rao (1943). *Proc. Nat. Acad. Sci. India*, 13, (3): 333-355. B. Sahni.

Some blocks are brown coloured, perhaps due to the presence of iron in the matrix, and are very suitable for investigation. On the other hand, a few are fully silicified and vitreous and are not at all amenable to staining; they present considerable difficulty in the investigation of the structural details of their plant-content. Parts of such sections and even some stained sections when covered with a coverslip and Canada balsam become almost transparent. Several media with different refractive indices from that of Canada balsam were tried for mounting. It has been found by experience that the sections should be permanently mounted on the slide with Canada balsam and stained. For temporary investigation and photography the sections should be flooded with water and covered with a coverslip. Glycerine too can be used, especially when long exposures are to be given during photography.

In one case it was felt necessary to take 'peel' sections, by etching the section with HF and smearing it with a thin layer of *Duco*. After it had dried up, it was pulled off, carrying with it the organic parts of the plant.

#### DESCRIPTION AND DISCUSSION

##### 1. *LYCOXYLON INDICUM*, gen. et sp. nov.

The following description is based on a single specimen found lying tortuously embedded in the matrix of block No. K11. The first section (obliquely transverse) and in many ways the most typical of all the sections so far available (Fig. 3), was obtained in a slice which was cut from this block for the investigation of *Pentoxylon* (see below; Srivastava 1935 p. 285; 1937 p. 273). In an endeavour to get further transverse sections, one more slice was cut, but then it was discovered that the axis was bent suddenly almost at right angles at this point and the section had passed through this region, an oblique longitudinal section being the result. Later, however, two more transverse sections (Figs. 1 and 2) were cut; the rest of the axis (not more than 3 cm. in any case) still remains uncut and lies embedded in the block.

##### *Stelar and cortical anatomy.*

##### *General structure.*

The specimen consists of a decorticated axis, with only the inner thick walled cortex and the xylem elements preserved, and is hardly 1-2 mm. in cross section. The vascular cylinder consists of a few xylem plates, arranged in more or less parallel rows, alternating with which are gaps obviously indicating the position of the phloem plates; the phloem itself is not preserved. In some sections the plates are V-shaped but this is obviously due to the lateral com-

pression of the axis before fossilisation, and is not at all the original condition. On the two opposite sides (in the figures upper and lower) the plates give place to smaller ones of xylem elements, arranged in the form of a V, W or a crescent. They are markedly more numerous and more irregular on the upper side in Fig. 1. This dorsiventrality is very similar to the condition found in the several species of *Lycopodium* belonging to the *Clavata* section. The stem may have been of a creeping habit, and if so, then the upper and lower sides in Fig. 1 may have been the dorsal and ventral sides of the axis. The tortuous way in which the specimen was lying in the matrix may, after all, be due to this plagiotropic habit of the plant.

#### *Structural details.*

The central cylinder, as stated, consists only of the xylem elements; there are three or four plates of 1-2 rows of comparatively large, more or less hexagonal tracheids ( $35\mu$  to  $50\mu$  in diameter). Phloem, which also must have been in bands, is not preserved and its place is taken up by gaps between the xylem bands. Phloem sheath, pericycle and endodermis too are not preserved and a circular gap (in a cross section) round the vascular cylinder possibly indicates their original place. An occasional bifurcation of the plates is met with (Fig. 1.) A cross connection between two adjoining plates, especially with the smaller arcs of xylem, is also occasionally seen (Fig. 6). The flanks of the xylem plates or arcs are occupied by a group of much smaller but more numerous protoxylem elements. Their free ends are, as a rule, slightly dilated, especially so in the case of the smaller arcs. This is again an anatomical detail in common with the *Clavata* section of *Lycopodium*. *Asteroxylon*, by the way, also shows this same feature. There is no evidence whatever of the presence of xylem parenchyma cells in the xylem bands (Figs. 1 and 5).

From the solitary oblique longitudinal section which, moreover, is not quite well preserved, it is impossible to give details of the size and form of the tracheids. But the scalariform pitting of the larger tracheids can still be recognised at places (Fig. 5). The protoxylem tracheids show a close spiral pitting.

Only a part of the cortex is preserved (Fig. 4), as is obvious from the fact that the majority of the marginal cells are torn. The cortex, as preserved, must have been the innermost cortical layer, and consists of a few rows of thick walled, slightly tangentially flattened cells, with their cell cavities considerably reduced.



*Stem or root?*—In the absence of the outer layers of the cortex, which would bear the leaf-traces and leaf-bases, if it were a stem, and in the absence of any attached fructifications, it must remain an open question whether this axis is really a stem or a root. The roots, too, of some species of *Lycopodium*, for example, have a similar stelar anatomy as the stem. To quote Holloway (1915 p. 299), "The long aerial adventitious roots of *L. volubile* also might be termed either stems or roots". The tortuous way in which it was lying in the matrix can be interpreted either way, as showing the habit of a root or that of a creeping stem. But if it is a stem, then the question is whether it is the primary axis, or a branch of secondary or higher order. According to Boodle (1900 p. 316), in *L. volubile* "in branches of four successive orders the protoxylem groups number 17, 14, 8 and 7 respectively". Then with this data in view, from the study of purely the number of protoxylem groups, which is round about twenty in this case, it appears, in spite of its minute size to be a primary stem. We have no means, however, of knowing what thickness of the cortical region was lost in decortication prior to fossilisation. It may have been full grown as the tracheidal walls are sufficiently thickened (Fig. 1). No useful comparison can be made with the root structure of any other pteridophyte, say the ferns, as here we are dealing with a concentric protostele.

*Resemblance with Lycopodium.*—The exarch, dorsiventral, banded type of central cylinder finds its exact parallel in the stems of the *Clavata* section of *Lycopodium*. The presence of a thick-walled inner cortex, indicating roughly that the next outer region of cortex may have been composed of softer cells, is in line with the structure found in *L. clavatum* and many other species of *Lycopodium*. The dilatation of the protoxylem groups at the free ends of the xylem bands and arcs of *Lycosylon* is also an important feature of general occurrence in *Lycopodium*, though not confined to this group. The occurrence of these characters in common between the two genera cannot be a mere coincidence. The idea that it points to a genetic relation between the two receives support from the occurrence, form and wide distribution in the Jurassic of the well known genus *Lycopodites*.

#### *Occurrence of the genus Lycopodites in the Jurassic.*

The presence of *Lycopodium*-like plants has long been suspected in the Mesozoic but till now all the species known have been found only as impressions—*Lycopodites*. The occurrence of this genus in the Jurassic strata has been now known for over a century. It had a world-wide distribution in the

Jurassic and several species have been reported from such remote countries as India, Scotland, Victoria, New Zealand and America.

*Lycopodites*—as is implied by the generic name—is supposed to be the impression of a *Lycopodium*-like plant and this supposition has gained more and more support when heterophyllous forms, branching forms and even cone-bearing specimens were successively discovered.

*Lycopodites gracilis* (O. and M.), a species described from the Rajmahal series as early as 1877, shows heterophylly, dichotomising stems and terminally borne cones, and is thus fundamentally similar in habit to certain species of *Lycopodium*, e.g., *L. volubile*.

Species of *Lycopodites* are already known from practically all over the world, and the fact that so far it has been unknown in a petrified state, can only be due to the general paucity of petrified materials from the mesozoic formations. *Lycoxylon*, after all, may be a petrified specimen of *Lycopodites gracilis* (O. and M.). This is the first record of a fossil plant from the Jurassic practically identical in its stelar anatomy with the living genus *Lycopodium*. The discovery of the entire cortical region and the fructification will be eagerly awaited.

It is remarkable how the giant Lycopods of the Palæozoic were succeeded in the Mesozoic by such diminutive types.

#### *The systematic position of Lycoxylon.*

To refer this plant to the living genus *Lycopodium* merely on the strength of its stelar anatomy may be rash. Due to the imperfection of our knowledge of its anatomy, coupled with the complete absence of any idea of its fructification, it has been thought advisable to institute a new genus *Lycoxylon* to accommodate it. It may provisionally be included in the family Lycopodiaceæ. In the family Lycopodiaceæ too, for its possible nearest allies, we must go to the *Clavata* section of *Lycopodium*.

The Jurassic age of *Lycoxylon* may indicate that it is a primitive member of the family. But the banded type of stele, which is regarded by many as a feature of the most highly evolved section of *Lycopodium*, and its geological antiquity, may appear as a combination of two radically opposite characters. Workers who read the evolutionary tendencies in *Lycopodium* in the reverse direction, may find in it some further geological support for their hypothesis. But after all, a reliance on negative evidence in palæobotanical work, even as in other fields, is never safe. There is no knowing when we may come across the *Selago* type of stele, too, from the Jurassic or from a still older formation.

*Diagnosis.*

**Generic.** *Stele of the banded type. Inner cortex made up of thick walled cells. Metaxylem tracheids with scalariform pitting.*

**Specific.** *Stele dorsiventral with 4-5 more or less parallel xylem bands. Bands usually two cells in width. Protoxylem groups about 20 in number and slightly dilated.*

*Summary.*

More or less decorticated axes, 1-2 mm. in thickness. Stellar anatomy similar to that found in the primary stems of the *Clavata* section of *Lycopodium*, with more or less parallel xylem bands in the middle and V or W shaped xylem arcs on the upper and lower sides. About twenty protoxylem groups occur at their free ends and are slightly dilated. Only the inner cortical layer consisting of thick-walled cells is preserved. The metaxylem tracheids show scalariform pitting and the protoxylem elements are spirally thickened.

II. *PENTOXYLON SAHNII*, gen et sp nov.*Occurrence and general structure.*

Sections of ordinary coniferous shoots are extremely common in my slides. But frequently also a peculiar type of stem section is met with, which has 5-6 steles arranged in a ring in the ground tissue (see plates 2, 3). The outstanding feature of these steles is that each of them shows profuse secondary growth in the centripetal direction (Figs. 8, 12, 18, 31).

Fragments of this stem, oblique fractures or crushed and distorted stems are met with in practically every block. As an extreme case, in Block No. K11 (about 7 cm.  $\times$  4 cm.) as many as fourteen stem sections of different sizes were seen on the exposed surface. Thus judging from its frequency of occurrence *Pentoxylon* seems to have been an important member of the flora, next only to *Teniopteris spatulata* and some typical coniferous shoots.

Usually the stems are small, 5 mm. to 1 cm. in diameter, but individual steles about a centimeter or more in diameter are not uncommonly met with. The softer cells of the ground tissue are generally poorly preserved, presumably because the stems had suffered a certain degree of desiccation before fossilisation.

*Anatomy of a typical stem.*

In a typical case the outline of the stems in a cross section is circular, about 5-6 mm. in diameter, with five equally developed steles, arranged in a ring in the ground tissue (Figs. 7, 9). Each stele consists of a lenticular primary

portion composed of a group of irregularly arranged tracheids, immersed in which are a few protoxylem tracheids (Figs. 15, 16, 18, 31). Primary xylem in the majority of cases is crushed or has escaped preservation and is represented by a clear space. It is surrounded on all sides by a compact ring of secondary wood which is equally developed all round during the first year's growth, but which from the second year onwards shows a marked tendency for profuse centripetal growth (Figs. 12, 31). This feature is of an unique nature and of great diagnostic value. In the youngest stage that has so far been discovered the primary bundle is surrounded by at least two years' growth.

*Ground tissue.*—The ground tissue is too indifferently preserved to allow a correct description. From the little patches which are sometimes preserved, they seem to be made up of thin-walled small cells interspersed in which are numerous groups of stone cells or sclerotic nests.

The ground tissue may be roughly differentiated into three regions, the pith, the stelar and the cortical. The pith originally must have been comparatively quite wide, but later much of its dimensions is lost due to the regular encroachment that is made upon it by the steles in their centripetal growth. The presence of numerous sclerotic nests is a characteristic feature of the pith. They are sometimes arranged in tiers forming incomplete horizontal diaphragms, giving the false impression of a discoid pith (Fig. 36). In a slightly older stem (slide No. K42/1), a continuous ring of serially arranged thin walled rectangular cells is found just immediately interior to the steles (Figs. 18, 31). This "jacket of cells" may be comparable with the "periderm" of *Rhexoxylon africanum* (Bancroft, 1913, pp. 87-103) and the "sheath" of ( )\*. It clearly delimits the medulla from the stelar region.

Just outside the stele is an almost complete ring of patches of compacted thick-walled cells resembling groups of pericycle fibres. This layer we may provisionally call the pericycle (Figs. 12, 32). The tissue outside the pericycle would be the cortex. The bulk of it seems to have been lacunar and possibly also traversed by many secretory passages. It was externally covered with bark.

The stelar region, i.e., the space enclosed between the 'pericycle' and the 'jacket of cells', contains five steles separated by a thin-walled tissue of conjunctive parenchyma, which is rarely well preserved. Alternating with the steles are found 1-3 wedge-shaped branch traces, consisting of radiating rows of tracheids (Fig. 10). They are more or less mesarch and collateral.

\*There is a gap here in the author's original MS.—B. Sahni.

*Vascular tissues.*—The lenticular primary portion of the stele consists of a mass of polygonal cells, a few of which are protoxylem tracheids, being of narrower lumen than the rest. In a cross section they may be circular in outline, the rest being polygonal (Figs. 15 and 16). In the longitudinal section they show the usual annular and spiral thickenings (Fig. 17).

As indicated above, each stele shows its own secondary growth, the primary portion being surrounded by secondary wood all round, equally in the first year, but later with an ever increasing quantity on the centripetal side. Secondary phloem, or what is probably secondary phloem, also develops remarkably well towards the pith and on the sides but the centrifugal secondary phloem is practically a nonentity. Primary phloem is indistinguishable. Secondary phloem on the flanks is so well developed that portions belonging to two adjacent steles nearly meet each other and are separated by only one or two layers of the original conjunctive tissue cells. Secondary phloem consists of squarish, radially arranged cells with their tangential walls thickened. Some of the parenchymatous cells contain some secretory substance (Fig. 33). It is not possible to distinguish the sieve tubes from the phloem parenchyma cells. The cambium layer is not preserved, but its probable original place is marked by a dome shaped gap between the secondary xylem and the secondary phloem (Figs. 18, 31).

Secondary wood is pycnoxylic, with well marked growth rings, due to the difference in the size and the thickening of the wall of the tracheids of the two seasons (Figs. 12, 31). There is no wood parenchyma, and no resin canals in the wood. The tracheids show uniseriate, round, contiguous bordered pits on their radial walls only (Fig. 38), but in older woods a biseriate, alternate, contiguous pitting is also met with in the wider summer tracheids (Figs. 42, 43).

The medullary rays are numerous, uniseriate, 1 to 14 cells in height, two to seven being the commonest number (Fig. 37). There is a single pit in the field occupying almost the entire field (Fig. 38). Each medullary ray cell is only slightly longer than broad and usually covers roughly one tracheid. The vertical walls of the ray cells tend to be straight rather than oblique.

*Variations from the normal type and anomalous secondary growth.*—Sometimes there are six otherwise normal steles present instead of the usual five (Fig. 9). Several sections showing this characteristic have been prepared from different blocks. Occasionally, however, one or a few of the five or six steles may be better developed than the rest, or may show a pronounced centrifugal growth

of the secondary wood, thus disturbing the otherwise circular contour of the cross-section. Two successive transverse sections (K65/1 and K65/2) are very interesting from this point of view (Figs. 13, 14). In this case one of the steles is much better developed than the rest. One flank of the centripetally developed wood of this stele, sweeps on to the exterior and there appears a radial split in the wood, between the centripetal and the lateral mass of wood, though the wood is distinctly continuous on the inner margin (Fig. 13). In the other section, a few millimetres higher up, the curved portion of the stele separates from the main stele and takes a sweep of a further 60°, so that what was centripetal or lateral a few millimetres lower, has gradually become centrifugal (Fig. 14). Thus the section now contains six steles, for all intents and purposes, as this newly formed stele, showing a profuse centrifugal wood, also contains a bit of the primary portion. The growth of the stem, henceforward, must have been of an anomalous nature. The newly formed stele may be termed an 'accessory stele.'

*'Short Shoots' associated with Pentoxylon.*

In addition to the typical form of *Pentoxylon* stems above described there are a number of thinner and shorter axes which appear to be the "short shoots" of the same genus.

Numerous cross, oblique and longitudinal sections are met with, each with 5-6 feebly developed bundles. The full sections are usually 4-5 mm. in diameter and 1-2 cm. in length. The cortex and pith are relatively wide with numerous sclerotic nests in them. On the periphery the section is clothed with bases of foliage leaves and scale leaves. At least the distal portion was covered with scale leaves (Figs. 27, 30). The leaf-bases have a swollen basal portion and an upper oblique continuation of it which at its edge is composed of a different type of cells, which may have formed an "absciss layer" (Fig. 29). No leaf, however, has ever been found actually attached to these shoots. In surface sections, the leaf-bases are seen to contain several vascular bundles arranged in a row forcibly reminding one of the row of vascular bundles as found in the midrib of *Taeniopteris spatulata*, which is also commonly associated with these "short shoots" (Fig. 25).

In a radial section the sclerotic nests in the pith are seen to lie in horizontal series, forming something like diaphragms (Fig. 29). Sometimes they lie irregularly scattered as in the typical *Pentoxylon*. They have no relation whatsoever to the leaf-traces.

The leaf-traces arise from the central cylinder and traverse the cortex, dividing frequently therein, and supply the upper portion of the leaf-bases (Fig. 29). In a transverse section one leaf-trace arises from the margin of each of the two adjacent vascular bundles, and the two curve apart in the cortex, forming an arc of a circle, with the open side facing the exterior. These divide twice or thrice in the cortex and finally the 6-7 bundles pass out to the leaf-bases (Fig. 26).

The radial pitting of the tracheids of these shoots also consists of circular, contiguous and uniseriate bordered pits.

The frequent association of these shoots with *Pentoxylon*, and the presence in them of 5-6 bundles, sclerotic nests and groups of stone cells taking up deep stain with gentian violet, uniseriate medullary rays and tracheidal pitting of the *Pentoxylon* type, had always been suggestive of the idea that these shoots were only a leaf-bearing part of *Pentoxylon*, something like the "short shoots," of *Ginkgo* and some conifers; typical *Pentoxylon* itself being the long shoot. A sparse amount of woody tissue in these stems only indicated the younger age of these shoots. The full length of these shoots, 1-2 cm. only, also favours this interpretation. This conclusion is further strengthened by the clear indication of 3-4 semicircular scars of possibly branches from the margins of a longitudinal section of *Pentoxylon*, about 3 cm. in length (Fig. 34). But because such questions can only be finally decided on the evidence of an actual organic connection of the two, it was my constant endeavour to discover a case, where an organic continuity of the tissues of the two could be demonstrated. A section from Block No. K4 showed two cross-sections, one of typical *Pentoxylon* and the other of this leaf-bearing stem, at a distance of about 3 or 4 mm. (Fig. 25). A thick slice 6-7 mm. in thickness was next removed from the block. This showed these two stems very closely approximated on the upper surface, but showed the cross-section of the typical *Pentoxylon* alone on the lower surface. This slice was later carefully ground by the author from both ends with carborundum powder, till the organic continuity of the two shoots became apparent.

This surface was etched with HF and peel sections with *Duco* were taken. But as the acid penetrated the woody tissues and as there was a constant fear of its being dissolved out by this acid, no more peel sections were taken. This slice was later on polished (Fig. 23). In this instance at least the two shoots are seen in organic connection, having a common ground tissue. The leaf-bearing shoot arises from the main stem at an angle of about 30°.

Another block, K117, shows what appears to be the cast of one of these short shoots, with a number of leaf-bases spirally arranged (Fig. 28). Its cross-section showed five light coloured patches in the centre, but the preservation was too poor for any anatomical study. This possibly shows the external features of the short shoot after the leaves had been shed.

The short shoots themselves seem to have been deciduous, as the presence of 3-4 branch scars in a longitudinal section of the long shoot indicates (Fig. 34). Again, excepting in the solitary case cited above, they are always found separately in the matrix. They must have fallen off only after the leaves were shed, as no attached leaf has as yet been observed. The presence of an absciss layer at the base of the short shoot seems very probable as the cells forming the branch scars (Fig. 34) are altogether different in shape and colour from the rest of the ground tissue cells. The short shoots thus perhaps never took any part in the skeleton of the plant itself.

*Fossil woods referable to this genus.*

The woody regions of two blocks, K80 and K62, are referred to here.

*Block No. K80.* The entire block is a piece of secondary wood about 6 cm. in length and less than 3 cm. in thickness, with the greater part decorticated. A transverse section from one end of this block shows it to be a pycnoxylic type of gymnospermic wood, with distinct growth rings. The woody portion consists of two very unequal parts, each with truncated margins (Figs. 20, 21). The growth rings are rather close, there being over ten growth-rings in a radius of about one cm. Whether there was a centripetal or a centrifugal development of wood, must remain a moot point till more complete structures are met with. The main piece of wood shows a prominent radial crack (seen in the photograph as a sinuous black line) which extends practically to the margin of the wood and separates the wood in two unequal sectors. The rift seems to have taken place quite early in life, as the growth rings of the two sectors seem to have developed independently of each other for ten seasons and more. Though the two sectors show a close similarity in their growth rings, still there is no absolute correspondence. The crack is invaded with parenchymatous cells—the 'dilatation parenchyma'. In addition to the radial rift, there is a tangential crack also near the inner margin of the smaller sector. This also is occupied by parenchymatous cells.

*A transverse section of the other end ( )\**

Though much of the wood is decorticated, still on one side a part of the cortical region (or is it the conjunctive tissue between two main steles?) is pre-

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\*The author's original MS. is incomplete here.—B. Sahu.



served. The parenchymatous cells are very badly preserved. But the interest of this region lies in the fact that it is traversed by four accessory xylem strands, showing secondary growth (Fig. 21), the most prominent of them being more or less fan shaped, showing a well marked radial crack. Near it lie two smaller strands, showing no special features, but the fourth and the largest seems to be an accessory stele, with a median tangential crack, perhaps representing the destroyed primary xylem tissue, with secondary wood showing two seasons' growth on either side of it.

This region is followed on the outside by a zone of small thin walled cells alternating with a row of resin spools. There are several pairs of such alternating regions. It is difficult to say with any degree of certainty whether it is a form of secondary cortex, or secondary phloem belonging to the thin strip of wood lying just beside it. This strip of wood itself may be a fractional part of another stele.

Radial and tangential sections of the wood show the usual features of the typical *Pentoxylon* wood.

*Block No. K62.*

One side of block No. K62, which has otherwise yielded some fine specimens of *Carnoconites* (Srivastava 1937, p. 274) has wood in longitudinal fracture on one side, which on sectioning shows the usual anatomical details of the secondary wood of *Pentoxylon*. The only notable variation is the presence of biseriate pitting in some of the summer tracheids, the winter ones showing the usual uniseriate pits. The summer tracheids are much broader than the winter tracheids, the former being about 24-40 $\mu$  in breadth and the latter about 12-16 $\mu$ . This is obviously a portion of an old wood of *Pentoxylon*. The biseriate bordered pits are alternate, meeting in the centre where alone their walls are straight, the rest being curved. Sometimes in the same tracheid some part show the usual uniseriate pitting, the rest biseriate (Fig. 42). Even a quincuncial arrangement is observed in some places (Fig. 43). Growth rings are pronounced. The rings are more close on one side but very much broader in the contiguous portion (compare Figs. 39 and 40).

This mass of wood towards the periphery is followed by a zone of what is either secondary cortex or secondary phloem. It is broadly divisible in two regions, an inner and an outer. This division is not a natural one, i. e., due to difference in structure of the two parts, but is due to the collapse and non-preservation of the thin-walled tissue adjoining the wood; the outer region being comparatively well preserved. The only noticeable parts in a longitudinal

section of the former region being long sinuous streaks of crushed cells, enclosing smaller or larger patches (? of resin) which take up readily a deep violet stain with gentian violet (Fig. 44). This region, though hardly 3 mm. in thickness, contains about a dozen such longitudinal rows. The outer region in a longitudinal section, about 4 mm. in thickness, shows about six alternating zones of radially seriated parenchymatous cells and groups of resin spools which appear squarish both in transverse and longitudinal section. The resin-like patches of this region appear white to the naked eye (Fig. 45). Each zone of radially seriated parenchymatous cells contains 6-7 rows of small cells, polygonal in transverse section and rectangular in longitudinal section. In a long section two such rows are joined up at short intervals by similar cells, and the squarish gaps thus left are occupied by slightly larger cells containing some resinous substances (Fig. 45).

### III. *CARNOCONITES*, a new genus of fleshy ovuliferous cones.

The presence of certain cone-like bodies forms a characteristic feature of many of the blocks. Two forms, one with bigger but fewer seeds and the other with smaller but more numerous seeds, can be distinguished even on a cursory examination. At first sight they look like ordinary coniferous cones, but when the surface is smoothed and smeared with water or clove oil and examined with a hand lens, a characteristic broad outer fleshy layer is at once discernible. The ovules, moreover, have their micropyles directed outwards. These two characters alone are sufficient to mark them out as cones totally different from those of any living species of gymnosperms and also different from all the fossil types so far described. Therefore these cones are referred to a new genus, *Carnoconites*.

They were fairly common in the flora, as they frequently occur in most of the blocks.

Generic diagnosis.—*Strobili bearing several ovules with micropyles pointing outwards. Outer fleshy and stony layer well developed. Nucellus totally free from the integument. Nucellar cone projects into the micropyle. Shrivelled remains of the female prothallus preserved in some cases. Ovular supply consists of a single vascular strand, which pierces the stony layer at the chalazal end and terminates below the base of the nucellus. Few seeds contain the remains of an embryo.*

Specific diagnosis of *Carnoconites compactum* sp. nov.—*Compact cones about 2 cm. x 1 cm., bearing 5 to 6 ovules in each longitudinal row, sometimes very few. Fleshy layer 1-2 mm. broad. Cones borne on long stalks which emanate from a central axis; 3-5 mesarch vascular bundles traverse the stalk. Cone axis shows 5-6 mesarch bundles*

DESCRIPTION OF *Carnoconites compactum*, sp. nov.

(Figs. 46—68) also 72, 73.

*General features.*

The majority of the cones are ovate in form but sometimes globose forms are also met with containing only a few seeds (see Figs. on plates 5, 6). Some rough idea of the construction of these cones can be had from radially and transversely fractured specimens. A transverse fracture from the middle of the cone is more or less oval and shows 4-6 ovules, usually six, cut in various planes. A radial fracture or a radial longitudinal section shows a median cone axis running along the entire length of the fructification attached to which are a row of seeds on either side, but the ovules at the distal and proximal ends are more obliquely borne. No two ovules are alike, as they are compactly arranged and thus much of the fleshy region undergoes mutual compression. A surface section shows a regular mosaic of the fleshy portions with a transverse section of the micropyle in some (Fig. 54).

*Detailed description of the seed.*

*The integument.*—The integument of the seeds is composed of two layers, the outer fleshy and the stony, the inner fleshy being totally unrepresented (Figs. 58, 61). The outer fleshy layer is lined on the exterior by small vertically arranged epidermal cells covered over by a layer of cuticle. The rest of the tissue of the outer fleshy layer is composed of two distinct types of cells; the outer rather extensive zone consists of large thin-walled polygonal cells, which often show a characteristic close reticulate pitting on all their walls (Figs. 72, 73). At some places, specially near the micropylar region, the bulk of the fleshy layer is composed of these cells alone. Though their pitting simulates so closely, even in the minutest details, the pitting of xylem tracheids, still from their number and position they do not appear to be tracheidal in nature. They seem to have served more or less as water reservoir cells, and kept the seeds turgid and in form. Such cells are not altogether unknown in other plants. They are found\*

This region merges insensibly with a layer of cells which is appressed to the stony layer and consists of rather elongated cells with some dark contents (Figs. 58, 66). They may be akin to the "resin" cells of some of the living conifers. (Sahni, 1920 p. 265).

\*MS. incomplete here.—B Sahni.

The stony layer is distinct, and consists of a compact zone of very thick-walled polygonal cells. But it is only in a few sections that the tiny lumen and the extremely thick cell wall is at all evident. Mostly they appear as a thin-walled tissue (Fig. 66). This deceptive appearance is due to the total destruction of the organic matter of the cell walls during fossilisation, leaving only the middle lamella which gives the false impression of a cell wall. The stony layer ends distally in the tubular micropyle which is lined throughout by it (Fig. 58).

*Nucellus*.—The nucellus is entirely free from the integument except at the base, where it is attached to it through a pad-like structure on which it is seated (Figs. 66, 67). Its distal end forms a cone-like structure which projects into the micropyle. Shrivelled remains of the female prothallus are preserved in many cases. Evidences, however, of the thin-walled cells composing it are seen in a very few places. Megaspore membrane thick. A few seeds contain traces of an embryo (Figs. 62, 63). Whenever present, it fills practically the entire cavity of the nucellus, though no cellular details of the embryo can be made out. Perhaps the ovules were shed in an early stage of development, but it is strange that the stony layer is always fully developed. The usual explanation of the presence of a period of rest between pollination and seed formation may hold good here also.

*Vascular supply*.—The ovular supply consists of a single vascular strand which pierces the stony layer at the chalazal end and terminates below the base of the nucellus in a pad-like structure (Fig. 66). That there was also an integumentary supply is not quite improbable. A few tracheid-like cells have been observed in the fleshy layer, but as the details of the pitting are still unknown, the question of the presence or absence of an integumentary supply must remain in doubt at least for the time being.

*Form of the nucule*.—As already indicated above, the ovules have no definite shape. The nucule, though of a more or less definite shape—oval and bicarinate—shows no well marked symmetry, hardly even in the micropylar region, where in a surface section of the cone it appears as a lenticular structure with the micropyle cut transversely and lying in the centre. A transverse section of the nucule just below the micropylar region is biconvex with one side more bulging than the other, with two lateral carinae (Figs. 46, 54). This bulge becomes more prominent in sections lower down. But the cross section at the chalazal end is more or less circular.

A median longitudinal section of the seed is usually ovate with the chalazal end almost flat and the micropylar end pointed (Figs. 56, 67).

The seeds may have opened along the carinae as an occasional split in some seeds indicates (Fig. 56). The carinae might as well be indicative of the principal plane of the seed.

*The pedicel and cone axis.*—The cones were borne on fairly long stalks (pedicels) which emanate from a central axis, the peduncle. Numerous cones were borne spirally on the peduncle, presumably in a 2-5 arrangement. The pedicels seem to have been borne at a small angle with the peduncle, so that some sections show three to four cross-sections of the pedicels and two to three cross-sections of cones distributed closely all round the peduncle (Fig. 63).

The pedicels for a short distance below the seed bearing region appear to be fleshy. A radial longitudinal section passing through this region shows below the epidermis a row of two to three radially arranged cells, placed end to end, like layers of palisade cells. This apparently fleshy region reminds one of the fleshy thalamus of some of the podocarps. The inner tissue of the pedicel consists of vascular and ground tissue cells. A transverse section of this fleshy region is more or less triangular or oval, with three vascular bundles in the centre (Figs. 62, 63). But sections cut lower down are almost always oval in form and show the usual three vascular bundles arranged in C-shaped fashion, the two lateral bundles being considerably larger than the central. Occasionally, however, the lateral bundles divide, each into two, resulting in five bundles as in the cone axis (see below). The bundles are collateral mesarch. Transverse sections of the pedicel through the non-fleshy region show a thin layer of outer cortex composed of ordinary parenchymatous cells. The cells of the inner cortex are slightly larger, considerably thick-walled, with dark inclusions in many (Fig. 69).

The cone-axis is about 2 mm. in diameter and frequently pentagonal in transverse section, with the ovules borne at the flat sides (Fig. 68). It consists of a mass of parenchymatous cells, scattered among which are many comparatively large cells with thick walls or with dark inclusions. A few of these, at any rate, may be even secretory canals.

The cone-axis is traversed by five collateral, mesarch, primary bundles, arranged more or less in a ring in the ground tissue (Figs. 68, 71).

*The peduncle.*—The peduncle is more or less oval in transverse section, with eight to nine vascular bundles arranged in a ring round an ill-defined broad medulla. The Cortex is broad and contains several pedicel traces, each with its characteristic three bundles arranged in a C-shaped fashion. Slide No. K140/4 (Fig. 63) shows a transverse section of a partly cracked peduncle, distinctly showing the central ring of 8-9 peduncle bundles with five pedicel traces in the cortex, each with its own trio of vascular bundles. The open side of the arch of the three vascular bundles of the pedicel is always towards the peduncle section (Fig. 74). But the case seems to be the reverse when they actually enter the pedicels (Fig. 62). The vascular bundles seem to undergo a certain degree of torsion when they enter the pedicels.

A striking feature of the fructification, a note of which could be taken at this stage, is the total absence of any clear cut scales, ovuliferous or bract.

*CARNOCONITES LAXUM* sp. nov.

(Pl. 8, Figs. 75-85).

Specific diagnosis of *Carnoconites laxum*, sp. nov.—*Lax cones about 3 cm. × 5 cm. with up to twenty ovules in each longitudinal row. Ovules smaller but more numerous than in C. compactum. Fleshy layer less developed, though distinct.*<sup>1</sup>

*NIPANIOXYLON GUPTAI* gen. et sp. nov.<sup>2</sup>

(Pls. 9-10).

1 In a diagnosis of his species published in 1937 (see p. 189 above) Srivastava added "On comparison with the original specimen it seems to be the petrified specimen of what is known in impressions as *Strobilites Pascoi* Sahní".—(B. Sahní).

2 For a brief description of this species see the abstract of the 1937 paper, reproduced above (p. 189). The definition of the genus *Nipanioxylon* as given there is, however, obviously incomplete and defective. For instance, Fig. 93 shows that the zone of secondary wood was not equally developed all round the primary bundle. The photographs in Pls. 9-10, Figs. 86-100 show that the Author had intended to give a fuller account, but no further notes are traceable and (with a few exceptions) it has not been possible to correlate the photographs with the original sections.

Until the material has been carefully re-examined it would be risky to define this genus and its relation to *Pentoxylon*. The attribution of some of the other organs figured in cross-section (Figs. 89-92, and 94-100) although referred in Srivastava's notes to *Nipanioxylon*, must remain problematical until the material has been critically investigated.—B. Sahní.

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## EXPLANATION OF PLATES.

All the photographs are from untouched negatives and were prepared by the author. The figured sections are preserved at the University of Lucknow.

### PLATE 1.

*Lycopoxylon indicum* gen. et sp. nov.

1. Slightly oblique cross section. (K 11/8)  $\times ca.$  58.
2. The same stem cut at a different level.  $\times ca.$  58.
3. The same obliquely cut. (K 11/2)  $\times 57$ .
4. The same section as in Fig. 3, to show structure of inner cortex.  $\times 57$ .
5. Oblique longitudinal section to show scalariform tracheids. (K 11/11)  $\times 245$ .
6. Part of the section in Fig. 3. (K 11/2)  $\times 88$ .

PLATE 2.

*Pentoxylon Sahnii* gen. et sp. nov.

7. Cross section of stem with partially preserved cortex. (K 11/11) × 4.
8. The same section × 15.
9. Cross section of a stem with six steles. (K 11/7) × 15.
10. Stem with 5 steles with outgoing strands (? branch traces). (K 11/10) × 30.
11. Part of another stem showing origin of branch traces laterally from the main bundles. × 25.
12. A stele showing well marked rings of growth with very little secondary wood on the centrifugal side; ? pericycle fibres; cortex. (30/4) × 30.
13. A stem with 5 unequal steles, the largest stele having a radial split. (65/1) × 4.
14. The same stem, at a slightly different level, showing the development of a sixth stele cut off from the largest stele. (K 65/2) × 4.
15. Part of a stele showing the primary tracheids. (K 68/2) × 83.
16. Part of the primary wood in the same stele. (K 68/2) × 230.
17. Annular and spiral elements of protoxylem. (K 68/1) × 650.

PLATE 3.

*Pentoxylon Sahnii* gen. et sp. nov.

18. A typical *Pentoxylon* stele with its surrounding tissue (see also Fig. 31). (K 42/1) × 15.
19. Longitudinal fracture of a small branched stem probably of *Pentoxylon*. Block (K 30) Nat. size.
20. Transverse section showing secondary wood. (K 80/5) Nat. size.
21. The same section enlarged. The growth rings in the two parts separated by the black sinuous line have developed independently. (see text) × 3.
22. Transverse section of an unusual stem, with seven or eight bundles, possibly showing branching. (K 119/1) × 4.
23. A relatively young *Pentoxylon* stem. (K 4/2) × 4.
24. Another section possibly from the same stem. (K 4/2) × 4.
25. Two closely associated shoots probably both belonging to the same species. One is a typical *Pentoxylon* with a small amount of secondary wood; the other is a very young axis (? short shoot) before secondary growth had begun. The transversely cut leaves are *Tamniopteris spatulata*; they were probably attached to the young shoots of *Pentoxylon Sahnii*. (K 4/1) × 4.
26. Another young axis (? "short shoot"), probably of *Pentoxylon*, showing origins of leaf-traces. (K 4/1) × 4.
27. Young axis (? "short shoot") surrounded by cross sections of leaves *in situ*. (K 30/6) × 15.
28. A young axis (? "short shoot" of *Pentoxylon Sahnii*) in external view, showing rhomboid persistent leaf cushions. Some of the cushions bear a horizontal row of about 7 vascular bundle scars. (K 117) × 4.
29. Longitudinal section of a "short shoot" like the above. (K 30/5) × 5½.
30. Longitudinal section of another "short shoot". × 5½.

PLATE 4.

*Pentoxylon Sahnii* gen. et sp. nov.

31. The same stele as in Fig. 18. × 38.
32. Groups of (?) pericycle fibres; branch traces in cortex. (K 30/4) × 30.
33. Transverse section, showing the ground tissue between two steles. (K 42/1) × 52.
34. Part of a longitudinal section of a stem showing the origin of a lateral shoot. (K 68/1) × 18.
35. A part of a transverse section of the stem to show the jacket of cells and the secondary phloem elements with their characteristic tangentially thickened walls.\* × 35.

\*The structure is not clear. The original section cannot be discovered. B. Sahnii.



36. Radial section through pith of a *Pentoxylon* stem, with sclerotic nests. (K 11/9)  $\times 15$ .
37. Tangential section of wood, showing typical coniferous structure; med. rays. 1-seriate. (K 11/5)  $\times 65$ .
38. Radial section of wood with typical coniferous structure with *Eiporen* in the "fields". Bordered pits 1-seriate, contiguous. (K 11/4)  $\times 100$ .

## PLATE 5.

*Pentoxylon Sahnii* gen. et sp. nov.

- 39, 40. Cross sections of secondary wood. (K 62/6)  $\times 30$ .
41. Radial longitudinal section of secondary wood showing the summer and the winter tracheids. (Probably K 62/7)  $\times 30$ .
42. Radial section of secondary wood. (K 62/7)  $\times 70$ .
43. Radial pitting of secondary wood. (K 62/7)  $\times 200$ .
44. Transverse section. (K 62/6)  $\times 30$ .
45. Longitudinal section. (K 62/7)  $\times 30$ .

*Carnoconites compactum* gen. et sp. nov.

46. Tangential section (opaque slice) photographed in reflected light. (K 102/2) Nat. size.
47. Tangential section (opaque slice) photographed in reflected light. (K 102/3) Nat. size.
48. Tangential section (the other face of the above specimen) photographed in reflected light. (K 102/3) Nat. size.
49. Roughly median fracture of a cone. (K 141) Nat. size.
50. Approximately median fracture of a cone. (K 65) Nat. size.
51. Tangential section (the other face of the opaque slice shown in Fig. 46). (K 102/2) Nat. size.
52. Thin section transverse (s). (K 140/2) Nat. size.
53. The same (K 140/2)  $\times 4$ .
54. Tangential section showing mosaic formed by the fleshy layers of contiguous ovules. (K 102/1)  $\times 4$ .

## PLATE 6.

*Carnoconites compactum* gen. et sp. nov.

55. Tangential (almost median) section. (K 62/1) Nat. size.
56. The same. (K 62/1)  $\times ca. 4$ .
57. Oblique section of cone passing longitudinally through the stalk of the cone. (K 36/6)  $\times 4$ .
58. Thin section showing portions of four ovules, with the sutures between their fleshy integuments. (K 16/5)  $\times 15$ .
59. Ovule in longitudinal section. (K 16/3)  $\times 20$ .
60. Roughly transverse section of a cone. (K 139/1)  $\times 4$ .
61. Obliquely transverse section of a cone. (K 15/3)  $\times 4$ .
62. Tangential section of a cone (? two cones pressed together). (K 36/3)  $\times 4$ .
63. Cross section of two contiguous cones with "peduncle" also cut transversely (a little above the centre of the figure). See Fig. 74. (K 140/4)  $\times 6$ .
64. Cross section of a cone with cone axis. (K 24/1)  $\times 4$ .

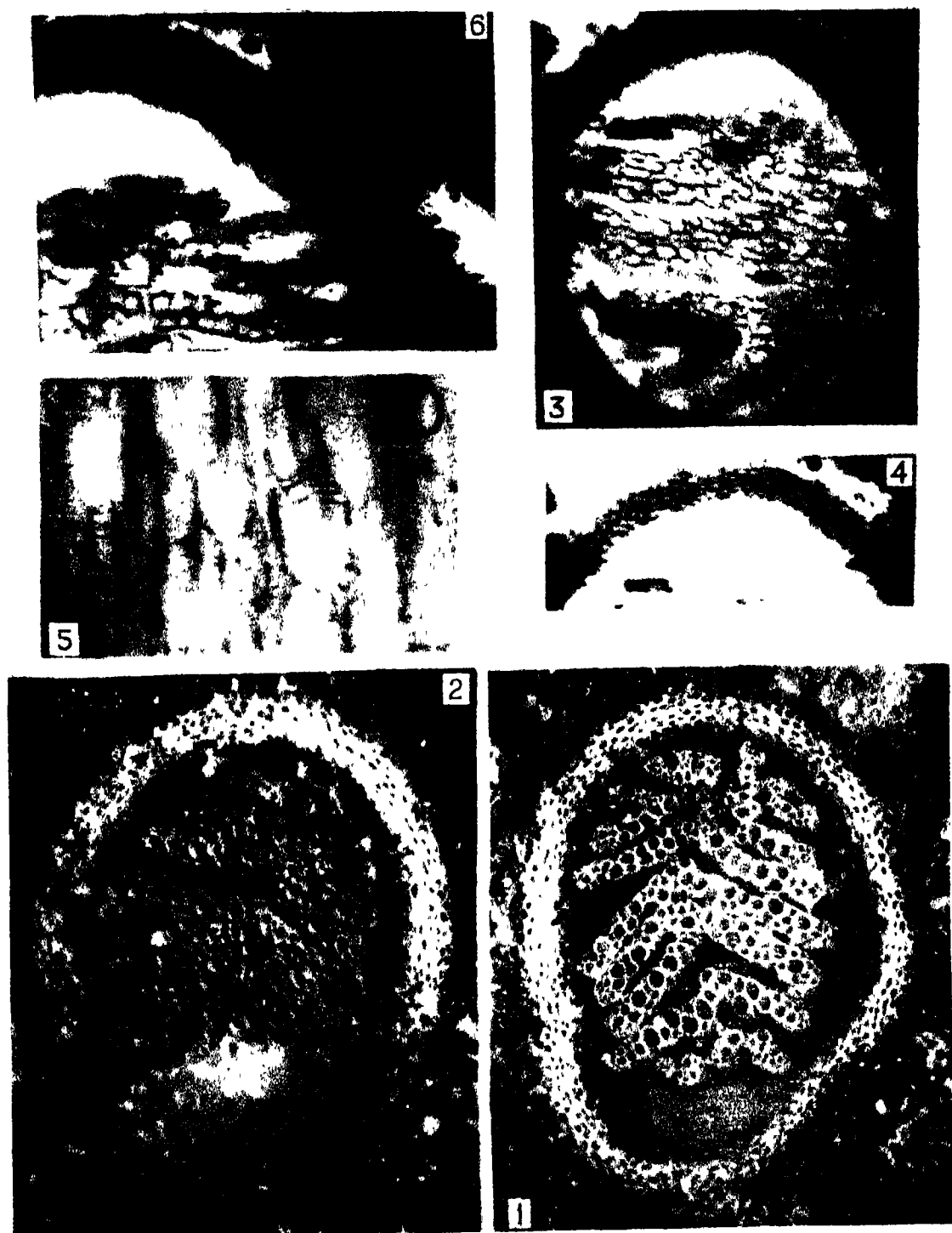
## PLATE 7.

*Carnoconites compactum* gen. et sp. nov.

65. Base of an ovule. (? K 36/3)  $\times 71$ .
66. Base of an ovule. (K 36/6)  $\times 39$ .
67. Two ovules from the section shown in Fig. 57. (K 36/6)  $\times 12$ .

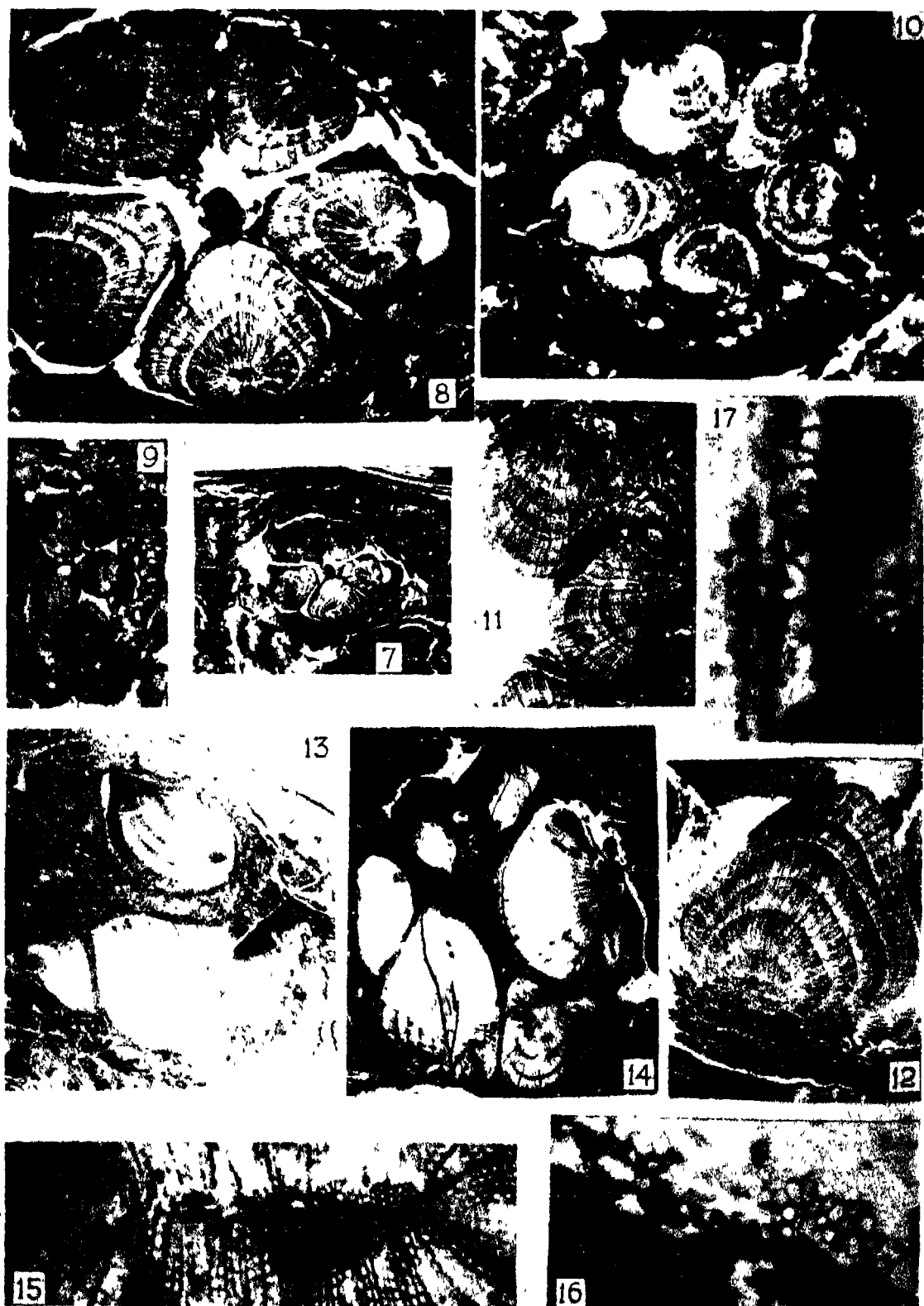


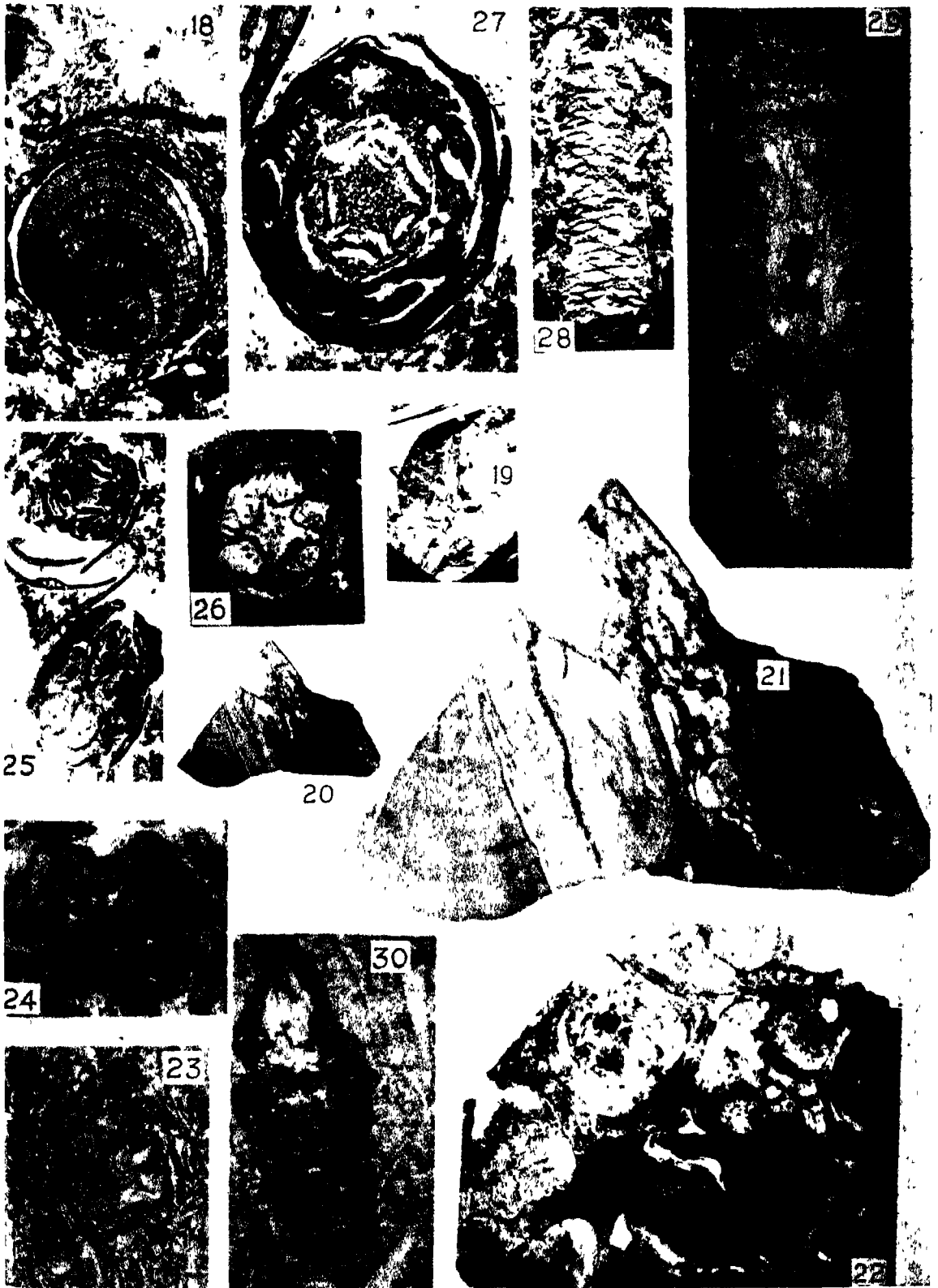




B P S Photo

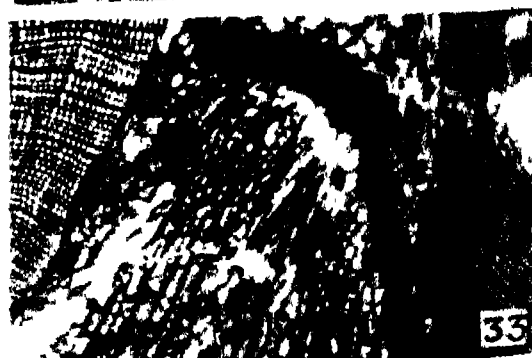
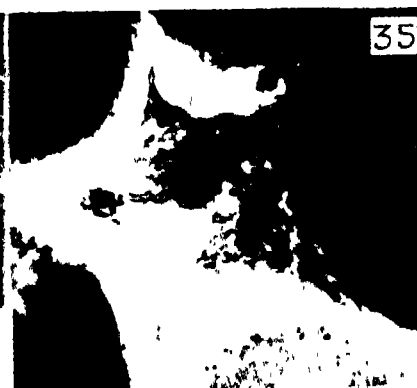
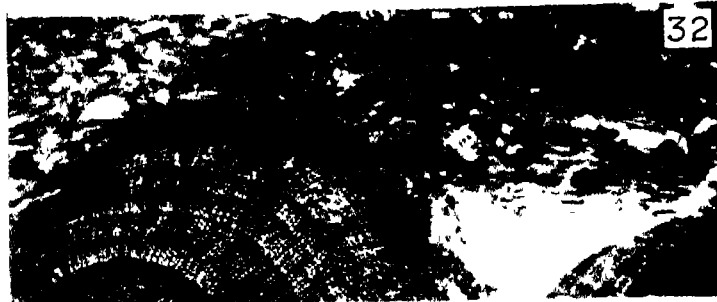
Figs. 1—6: *Lycozylon indicum* gen. et sp. nov.





B. P. S. Photo.

Figs 18—30: *Pentoxylon Sahnii* gen. et. sp. nov.





B. P. S. Photo.

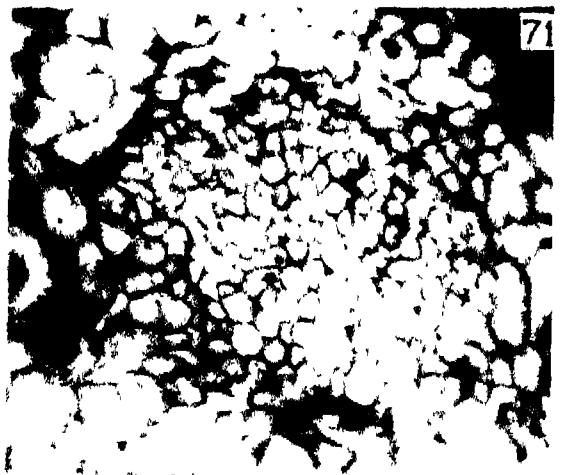
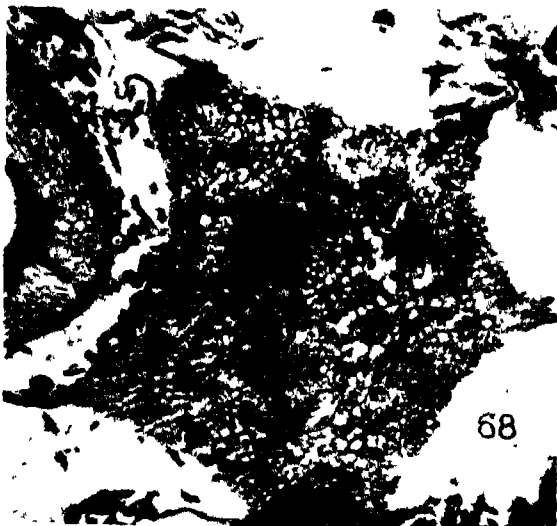
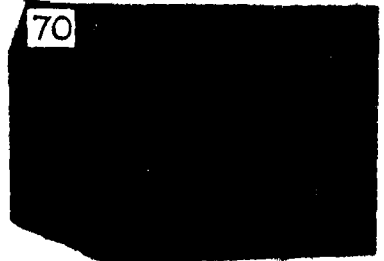
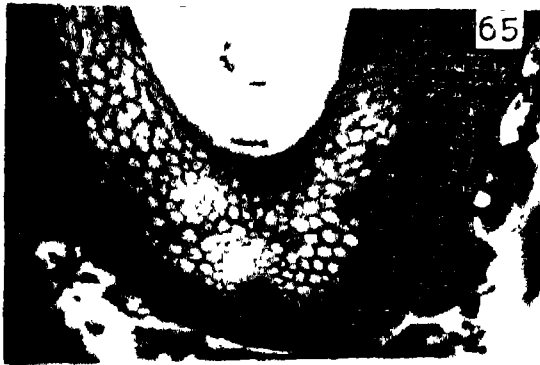
Figs. 39-45: *Pentoxylon Sahnii* gen. et sp. nov.

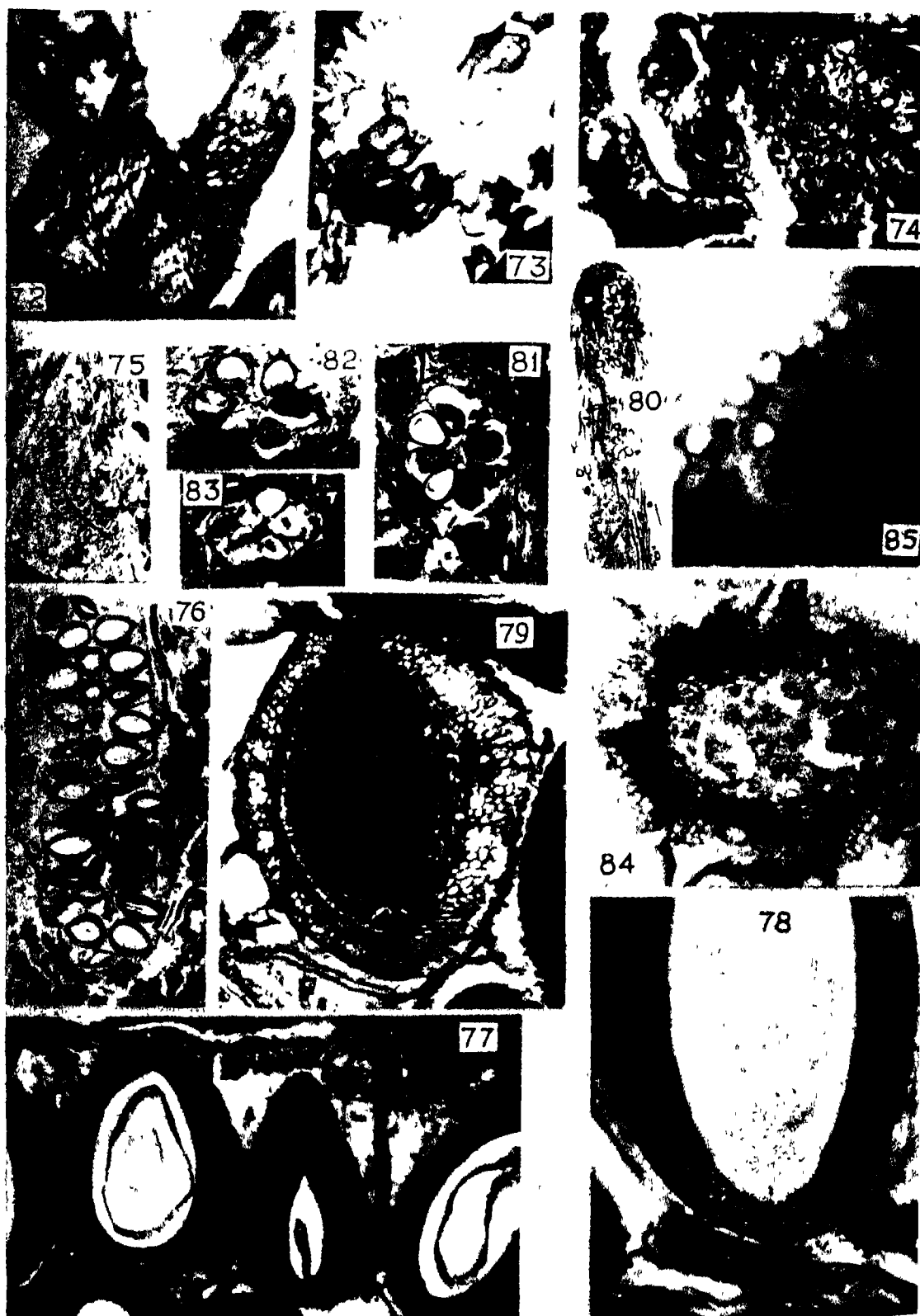




B. P. S. Photo.

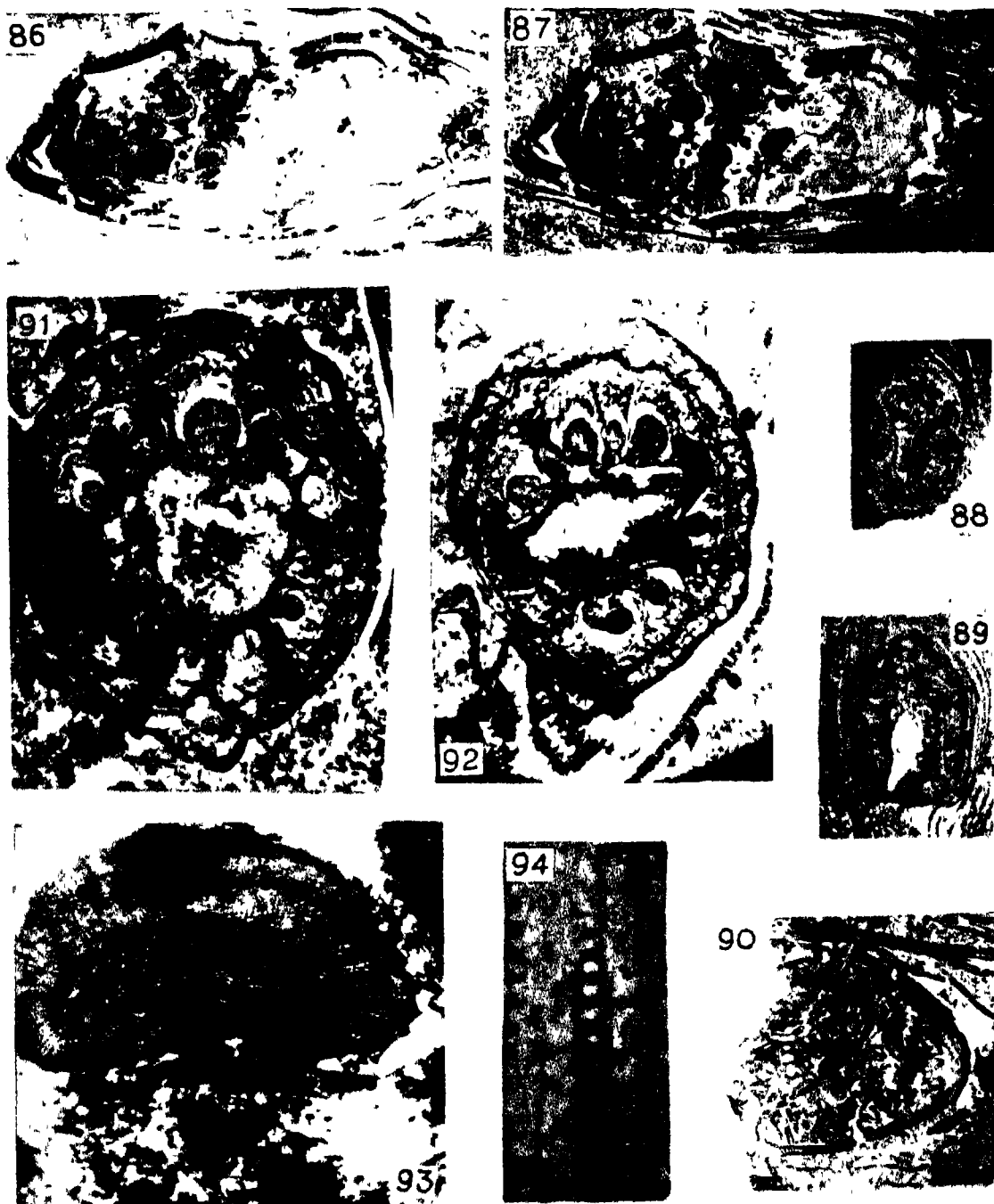
Figs. 55-64. *Carno onites compactum* gen et sp nov





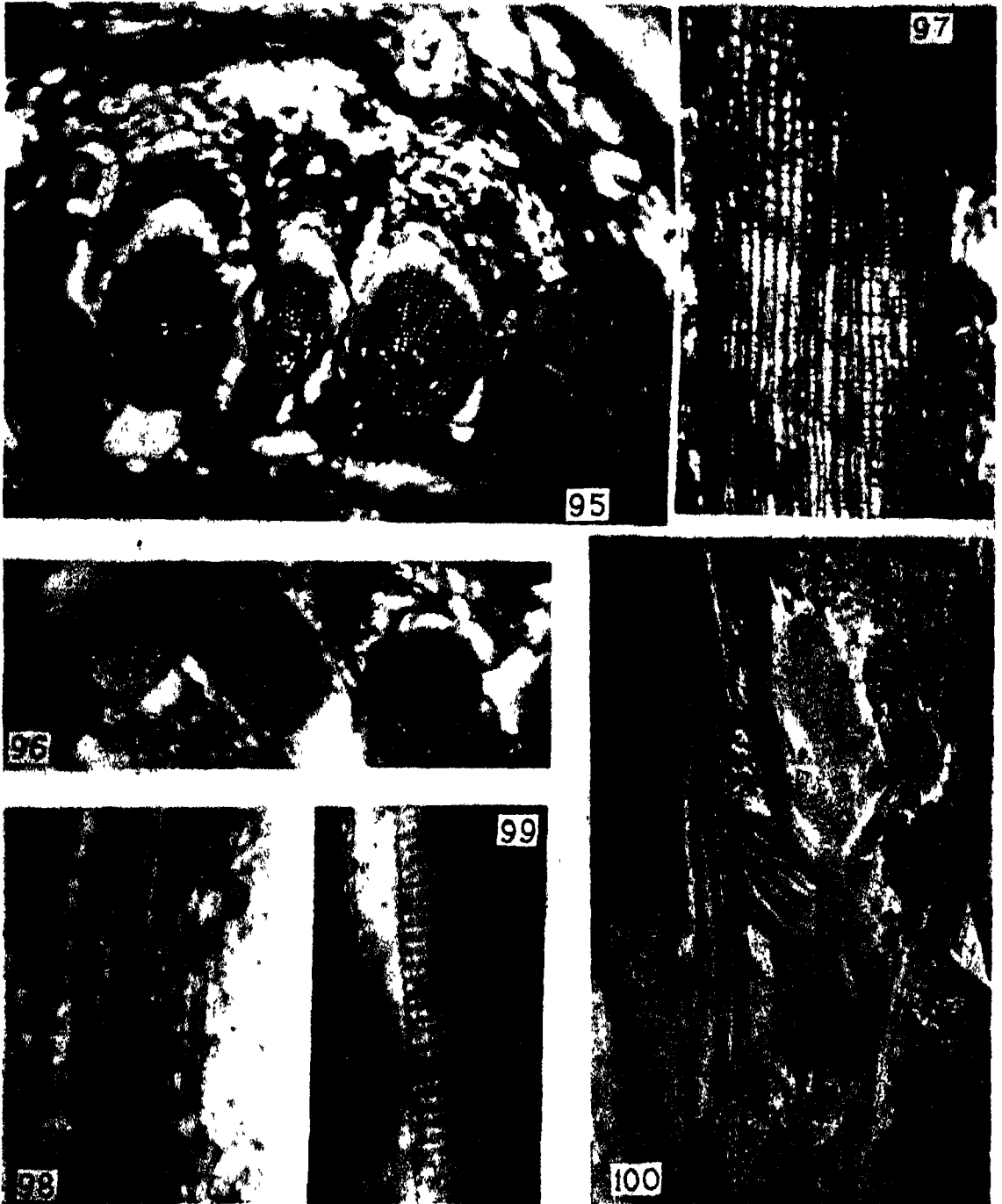
B. P. S. Photo.

Figs. 72-74: *Carnocontes compactum* gen. et sp. nov.



B. P. S. Photo.

Figs. 86-88, and 93: *Nipantioxylon Guptai* gen. et sp. nov.  
 Figs. 90-92, and 94: ? *N. Guptai* gen. et sp. nov.



B.P. S. Photo

Figs. 95-100. ? *Nipantoxylon* Gupta gen. et sp. nov.





- (8. Cross section of a cone axis, with attached ovules. (K 62/3)  $\times$  28.
- 69. Cross section of pedicel of a cone. (K 36/4)  $\times$  50.
- 70. (? K 140/4)  $\times$  245.
- 71. One bundle of the cone axis shown in Fig. 68 (K 62/3)  $\times$  230.

PLATE 8.

*Carnoconites compactum* gen. et sp. nov.

- 72. Cells of outer zone of outer fleshy layer of integument. (K 62/1)  $\times$  215.
- 73. The same. (K 62/1)  $\times$  52.
- 74. Peduncle from same section as in Fig. 63. (K 140/4)  $\times$  15.

*Carnoconites laxum* gen. et sp. nov.

- 75. Median longitudinal section of a cone. (K 208) Nat. size.
- 76. Tangential longitudinal section of another cone. (K 117/1)  $\times$  4.
- 77. Part of the same conc.  $\times$  20.
- 78. One of the seeds from the same cone.  $\times$  44.
- 79. Another seed from the same cone.  $\times$  38.
- 80. Thin section showing several cones cut transversely. (K 62/2) Nat. size.
- 81. Cross section of a cone. (K 67/1).  $\times$  4.
- 82. Transverse fracture of a cone. (? K 187/1)  $\times$  4.
- 83. Cross section of a cone. (K 62/4)  $\times$  4.
- 84. Cone axis from a transversely cut cone. (K 62/2)  $\times$  47.
- 85. (? K 140/4)  $\times$  245.

PLATE 9.

- 86. *Nipanioxylon Guptai* gen. et sp. nov. Cross section of stem (unstained). (K 19/11)  $\times$  4.
- 87. *N. Guptai*. The same section (stained with gentian violet).  $\times$  4.
- 88. ? *N. Guptai*. Cross section of another stem. (K 19/3)  $\times$  4.
- 89. ? *N. Guptai*. (? K 19/2)  $\times$  4.
- 90. ? *N. Guptai*. (? K 19/2)  $\times$  4.
- 91. ? *N. Guptai*. Cross section of a stem. (K 42/2)  $\times$  22.
- 92. ? *N. Guptai*. Cross section of a stem. (K 42/3)  $\times$  22.
- 93. *N. Guptai*. Cross section of a bundle from the stem shown in Figs. 86, 87. (K 19/11)  $\times$  41
- 94. *N. Guptai*. (? K 19/10)  $\times$  400.

PLATE 10.

*Nipanioxylon Guptai* gen. et sp. nov.

- 95. (? K 42/3)  $\times$  79.
- 96. (? K 19/2)  $\times$  69.
- 97. (? K 19/8)  $\times$  100.
- 98. (? K 19/10)  $\times$  124.
- 99. (? K 19/8)  $\times$  500.
- 100. (? K 19/9)  $\times$  15.





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